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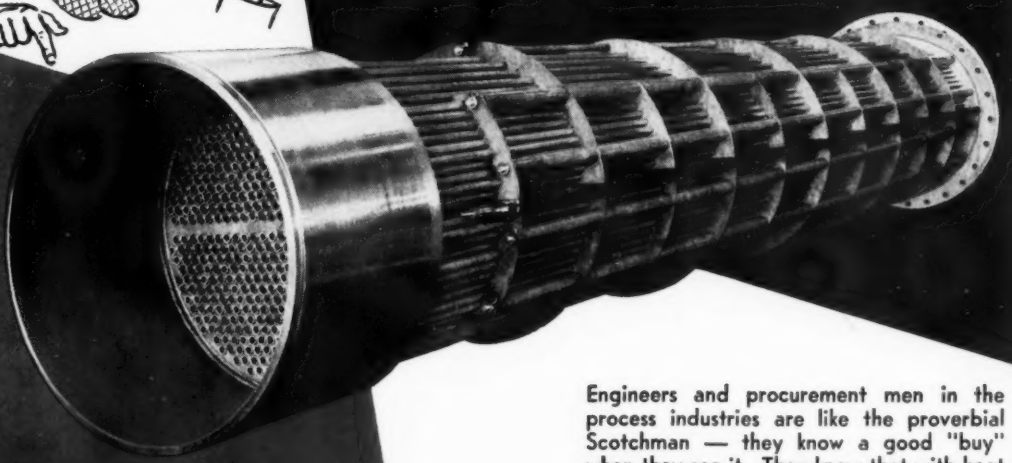
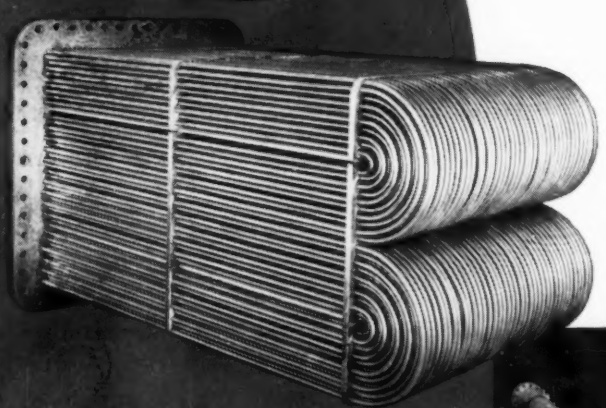
TECHNOLOGY REVIEW

January 1951

"A GOOD BUY IN HEAT EXCHANGE"





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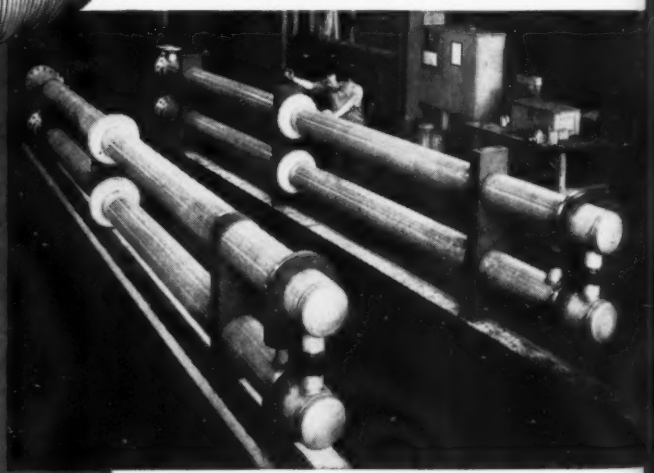

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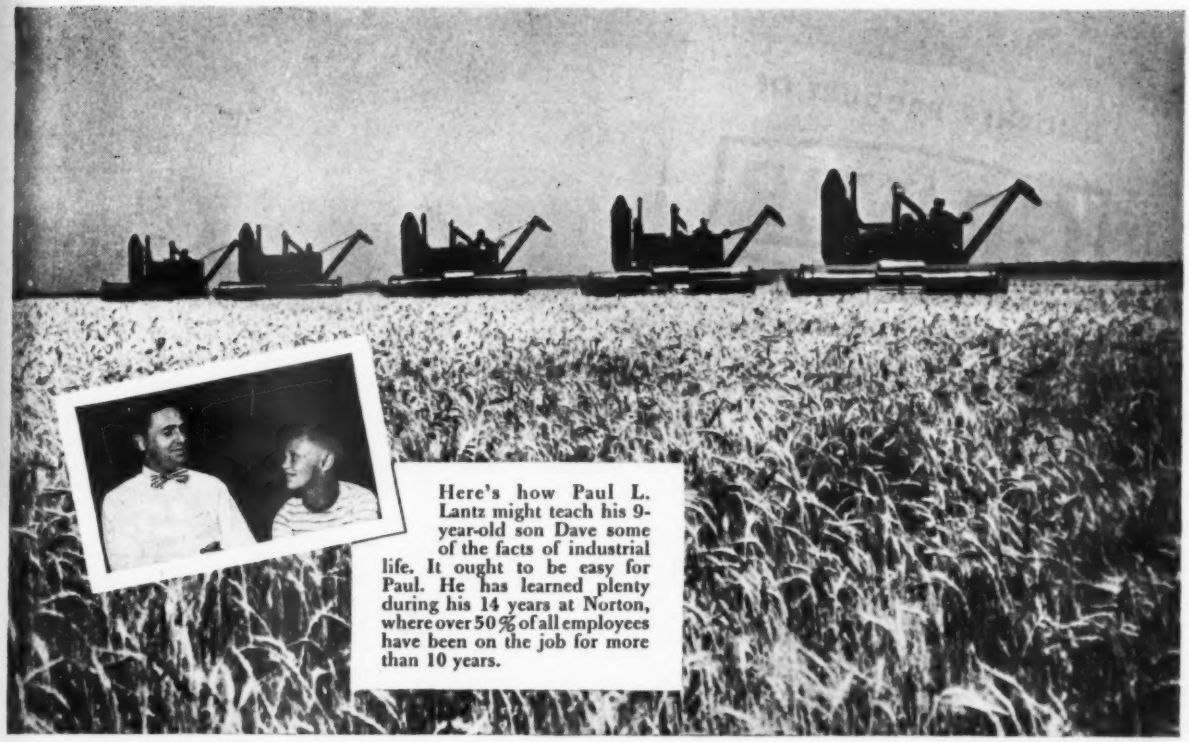

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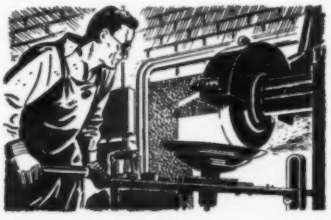

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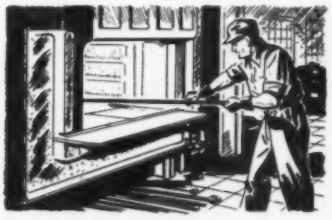

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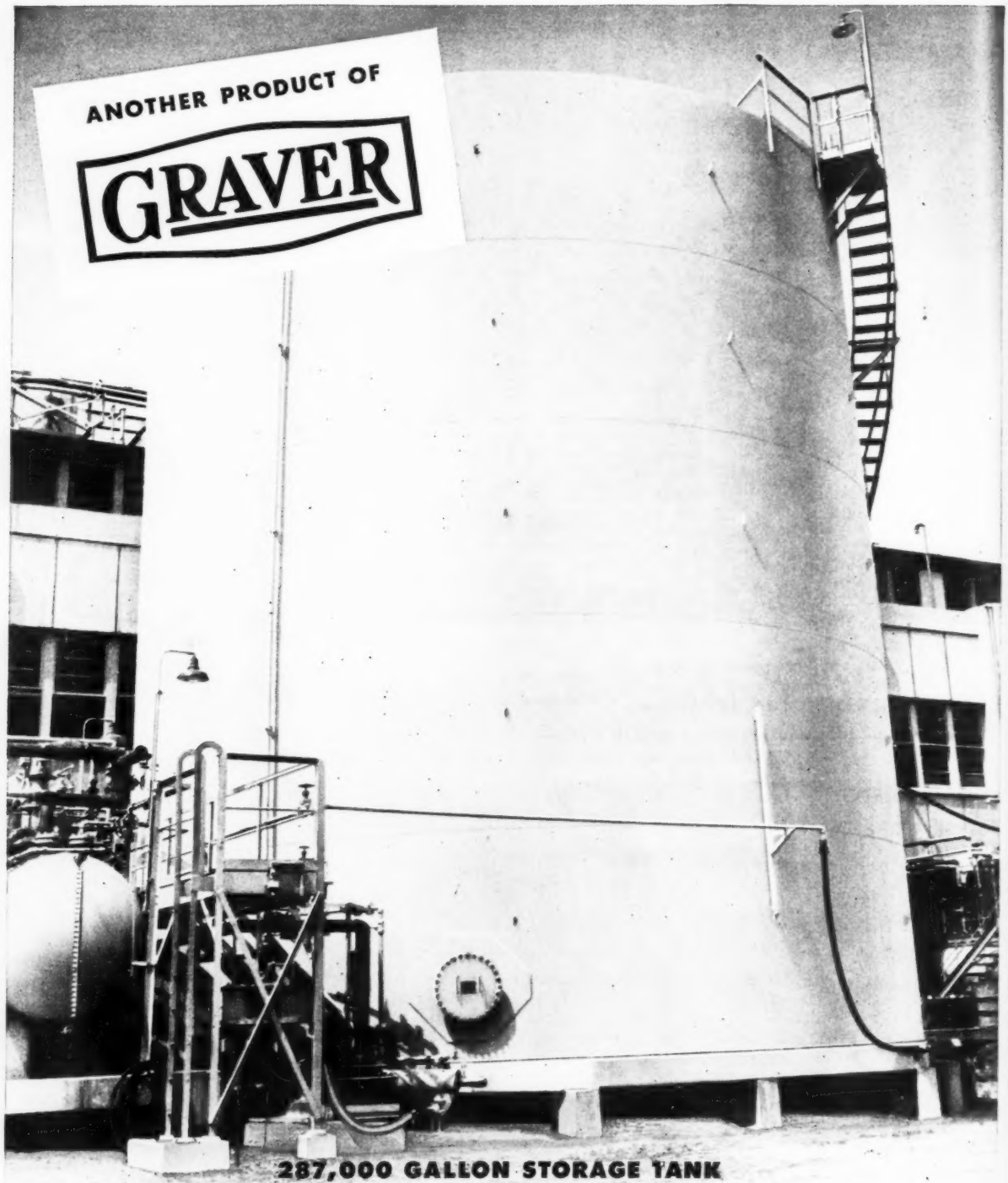

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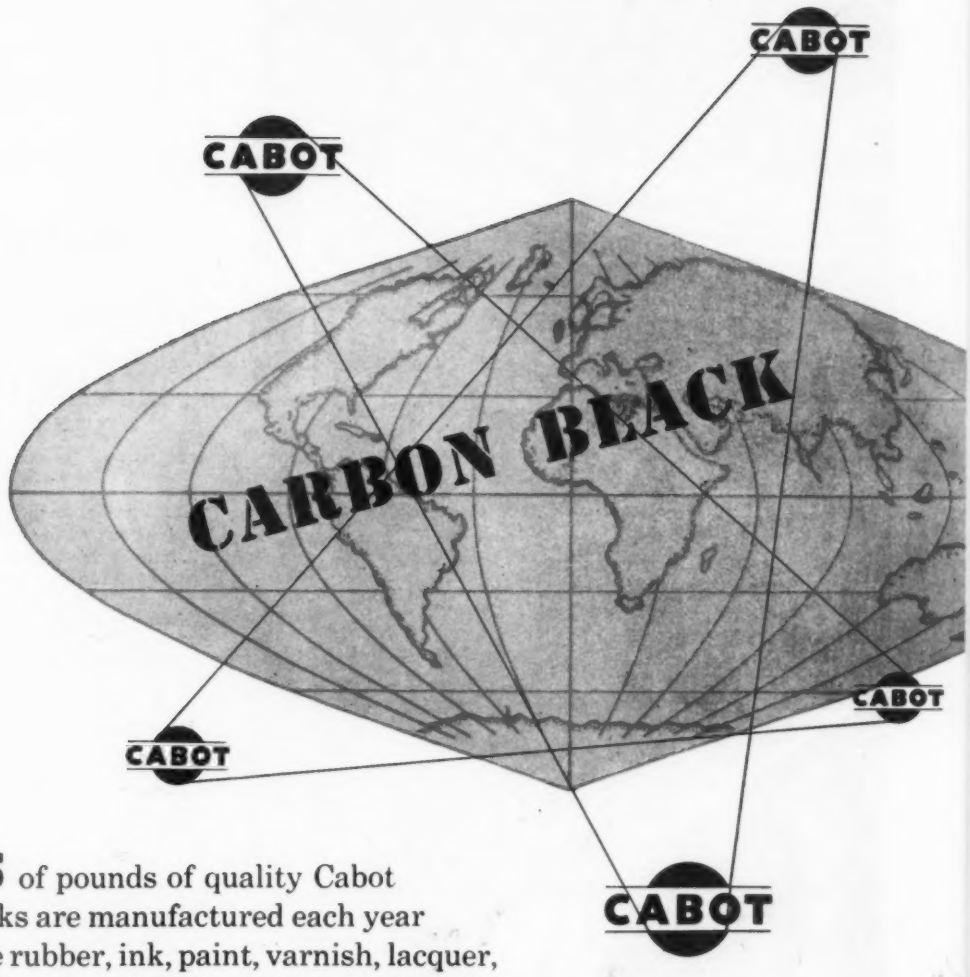

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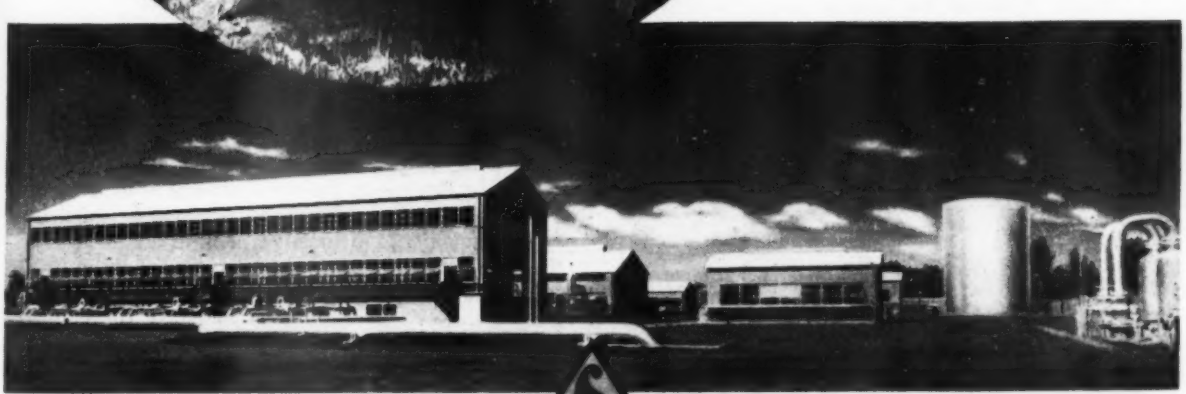

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THE TABULAR VIEW

Smoke Hole. – This month marks the centennial of the first construction of the Hoosac Tunnel which our grandfathers planned in order to bring the industrialized northeast section of the country into commercial contact with the rapidly growing West. The drilling of the tunnel, through five miles of rock, presented an unusual challenge to engineers of the middle Nineteenth Century, but out of the 25 years of construction effort, there emerged newer and safer engineering practices of great importance. The saga of this engineering feat is ably recorded (page 141) for The Review by E. H. CAMERON, '13, whose articles on the historical aspects of engineering ventures have become well known to Review readers during the past five years. Mr. Cameron is head of the Technical Publications Division of Jackson and Moreland, well-known Boston firm of consulting engineers. Mr. Cameron's professional activities have been entirely in the field of civil engineering, and embrace projects in New England, the Middle West, and Southwest. They include the design of bridge construction details, and engineering supervision of various factory enterprises, flood-protection work, and steam systems.

Ship Hulls. – The fundamental unchangeability of ship hulls throughout the ages is emphasized (page 147) by WILLY LEY, editorial associate of The Review since 1944, and writer on a wide variety of technological topics. Mr. Ley's present study surveys a few unusual designs which have aimed to increase some desirable property of ships – usually their stability – and shows that radical departures from traditional ship shape have usually been found lacking. At any rate, there appear to be few cases on record where drastic modifications of hull design found use over an extended time. Mr. Ley has been engaged in several years of research activity at the Washington Institute of Technology during World War II, but his primary interest is interpreting science through his writings.

Society's Headaches. – The accelerated pace at which technological progress alters our way of living is discussed (page 150) by PAUL MEADOWS, Associate Professor of Sociology at the University of Nebraska, and during the past several years a frequent contributor to The Review on the social aspects of technology. Professor Meadows shows the interrelationships between invention and society's need to adapt itself to the changed conditions which important discoveries bring about. It is not the technological change which causes society's headaches so much as the rate at which invention proceeds that makes it difficult for society to alter its thinking and mode of life with sufficient rapidity to keep up with technological advance. Professor Meadows was a research associate in a Rockefeller Foundation research project in the humanities. He received his doctorate from Northwestern University in 1940, and since then has been teaching sociology, with a major interest in the human aspects of modern industrialism.

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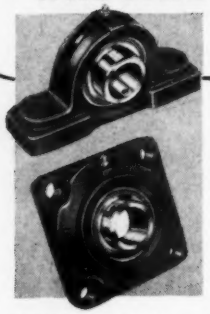

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MAIL RETURNS

Covered Bridges

FROM GEORGE H. BURT, '20:

I was interested in reading the article in The Review (December, 1950, page 83) in regard to covered bridges in New England, most of which seem to have been built 100 to 125 years ago. After I left Boston last June, I drove up through Maine, northern New Hampshire, and Vermont and happened to cross several covered bridges.

During my childhood here in the Middle West I had occasion to see several of the old-time covered bridges here which long since are gone, and I remember the story told to me at the time — that the reason for enclosing the bridges was primarily to prevent exposure to attack by Indians, rather than to give protection against weather, or to provide an enclosure for town meetings, as suggested in The Review article.

Since June I have tried to verify this history of the reason for the covered bridge and have been unable to find any explanation of the "why" of the covered bridge.

My observations last summer confirmed my previous recollections that the covering contributes no structural strength. The explanation given in The Review, that it offered a place for town meetings, as well as a convenient polling mechanism, would not seem to justify the use of the additional building lumber required; nor does it seem reasonable that in 1835 the populous was so poorly clothed or that the exposure to the elements in crossing an open bridge, as compared to the wooded areas on either side, would be such a hardship as to invite any consideration of the additional cost of such a structure.

The question has aroused my curiosity, and perhaps I may be able to arouse yours to the same extent so that you can find the answer and advise me.
Flossmoor, Ill.

[*Although the old covered bridges present a certain picturesqueness for today's generation, it may be that that quality was founded on practicability. There must have been good reason for adopting a style so uniform in the numerous covered bridges, and the one that the editor has heard most often is that these hooded coverings provided good protection for the flooring of the structure against the elements. — Ed.*]

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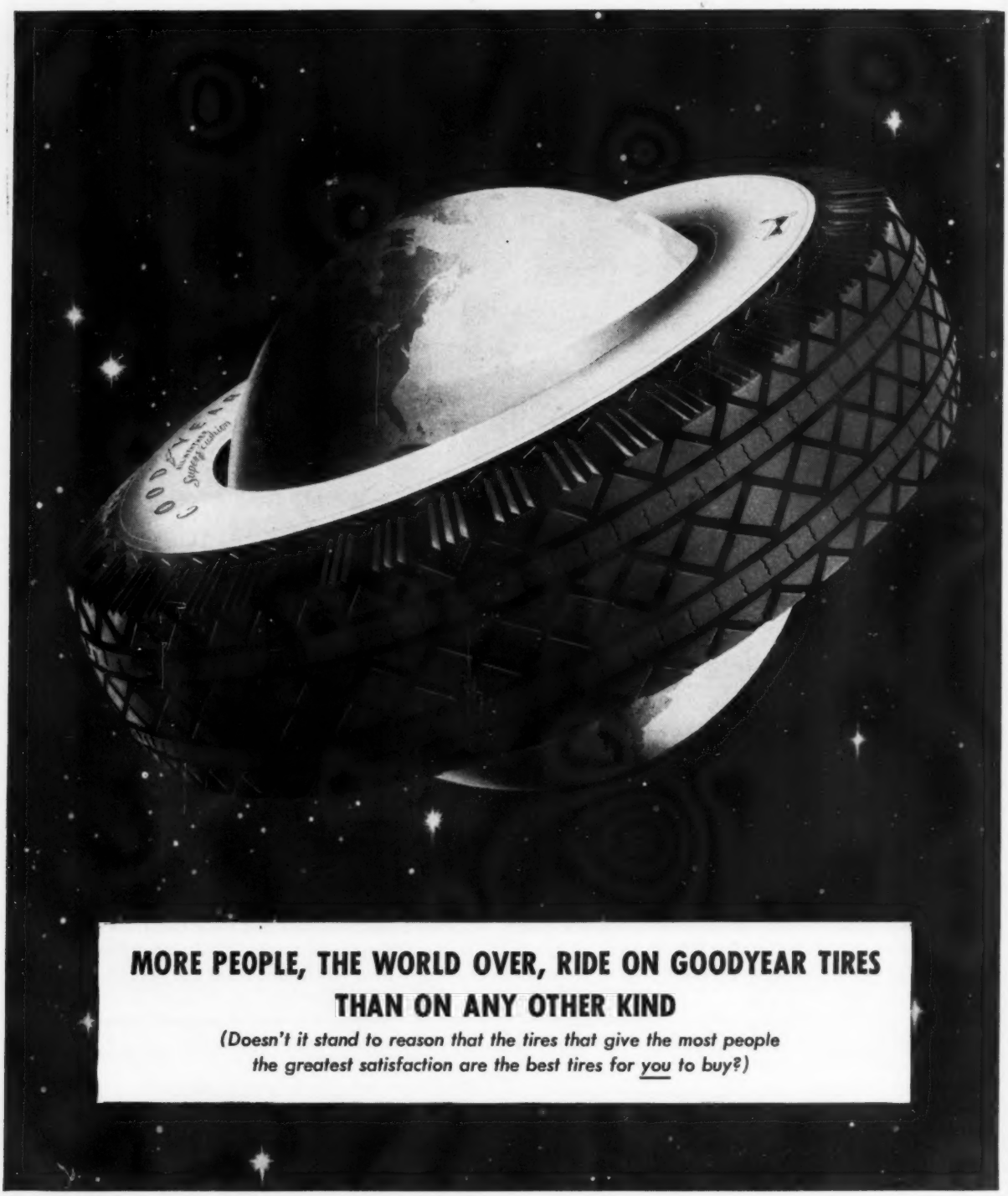

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Sanders from Black Star

Waterfalls of Light at Grand Central

THE
TECHNOLOGY REVIEW

Vol. 53, No. 3 January, 1951

The Trend of Affairs

Engineers and National Defense

MARKING the opening of the second half of the Twentieth Century, the year 1951 brings less prospect for happiness and prosperity than other new years of the past. Since the end of June, troops of members of the United Nations have been engaged in a shooting war in Asia. The state of national emergency, which has been proclaimed for the United States, emphasizes the need to utilize to the fullest all of our resources for national defense. The pattern is reminiscent of a decade back.

Very much against its choice, the nation is once more forced to go on a war footing for the third time in a generation, and heavy demands will be made on our man-power resources. All activities will feel the pinch, but the demand for man power will probably fall heaviest on scientists, engineers, and medical personnel. The advanced technological state of our industrial society requires a minimum of 20,000 engineering graduates annually for normal peacetime operations, to which must be added whatever numbers are required for civilian defense and the needs of the armed forces. Under the past "cold war" circumstances, 30,000 graduate engineers each year was a conservative minimum estimate of this nation's requirements, and the figure will certainly advance sharply as our defense needs mount.

Recognizing these facts, real concern can be expressed at the drop in enrollment in this country's engineering schools which has already taken place. But a survey recently conducted by the American Society for Engineering Education, under the direction of Solomon C. Hollister, Dean, college of engineering at Cornell University, indicates that the trend is toward a further decrease of enrollment in engineering schools for the next few years. Although administrators of engineering schools have been concerned about the decrease in engineering enrollment since the spring of 1950, the critical state of engineering education became evident last fall when enrollment dropped about 25 per cent from the preceding year, and some of the large engineering institutions reported that their enrollment had been cut in half during the past three years. So far as the number of its students is concerned, M.I.T. has not suffered, although it is no longer possible to make student selections on the same level of talent and ability as was possible shortly after World War II.

Studies made by the American Society for Engineering Education indicate that, unless the size of the entering classes is increased appreciably, the present enrollment of 130,000 students is likely to drop to about 105,000 in 1951, with a further reduction to 90,000 in 1952. Likewise, the survey indicates that, although 30,000 men will obtain engineering degrees in June, 1951, the number of graduate engineers is likely to drop to 21,900 in 1952, 17,000 in 1953, and 12,400 in 1954. Made last fall, these estimates do not take account of students who leave college because of the comparatively modest selective service requirements then in force. If these are taken into account, it appears that, at best, we cannot count on more than 18,000 engineering graduates in 1952, 14,000 in 1953, or 9,000 in 1954. This number of engineers will not meet our present normal civilian needs, let alone the stepped-up requirements imposed by civilian defense and the armed services.

During World War II, deferments were not made for competent students to carry on a normal course of study in science and engineering; instead we embarked on a program of accelerated training, and lived off our stock pile of scientific knowledge. Such a program was inimical to the best long-term interests of the nation.

All present indications are that the safety of the nation – now, and in the future – will require at least 30,000 engineering graduates each year. We are not now meeting that need, and the present trend is in the wrong direction.

Photos by Harold E. Edgerton, '27

(Above): *Explosion of a four-inch cube of high explosive taken with a four-microsecond exposure. A shutter delay of 13 microseconds was introduced after light was first picked up by a phototube. The dark areas correspond to the edges of the cube.*

(Below): *Photograph of the cube before detonation. The scale of the two pictures is the same.*

Microsecond Photography

A CAMERA shutter without moving mechanical parts, and which makes possible exposure in the region of from four to 10 microseconds, is one of the latest products of research developed by members of the Institute's group of scientists and research workers. Developed by a research team which includes Professor Harold E. Edgerton, '27, of the Department of Electrical Engineering, and Kenneth J. Germeshausen, '31, and Herbert E. Grier, '33, research associates of the Department, the new shutter has many interesting possibilities for industrial research by photographic methods. It is especially well suited to the study of explosions and luminous discharges, but is not limited to such applications. Except that it is considerably thicker than conventional shutters, and therefore requires somewhat greater space back of the lens, the magneto-optic shutter can be used with any conventional type of camera and lens system to provide good definition throughout a viewing angle of about 30 degrees or more.

Key element in the new camera design is the magneto-optic shutter which, because it has no moving mechanical parts, makes possible satisfactory exposures as short as a few microseconds. The shutter makes use of an effect, discovered by Michael Faraday in 1845, by which transparent bodies in a mag-

netic field rotate the plane of polarization of light passing through them.

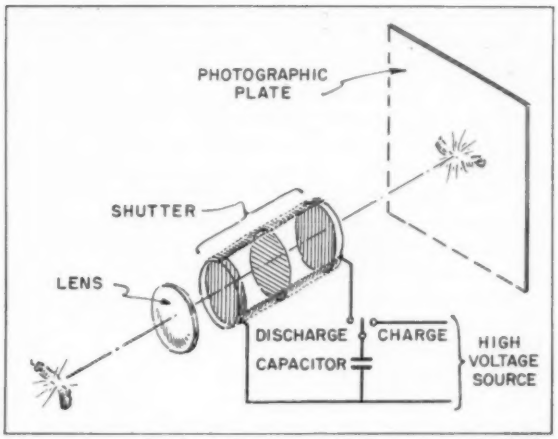
Essentially, the shutter consists of three sheets of polarizing material, the plane of polarization of the center being at right angles to the planes of the end elements. These polarizing plates are cemented between thick discs of strain-free, extra-dense, flint glass. Filters at the ends of the shutter restrict light passing through the shutter to a narrow band in the visible spectrum. Surrounding the shutter, which is made up as a cylindrical sandwich, is a coil of wire into which a pulse of current may be discharged from a condenser which has been previously charged to several thousand volts.

Under ordinary circumstances, the shutter is extremely opaque, passing something like one one-billionth of the light incident on its optical axis. Such high optical density is essential when recording photographically the action taking place in self-luminous bodies. When a condenser, charged to a potential of several thousand volts, is suddenly discharged through the coil surrounding the shutter, the current through the coils establishes a magnetic field of high intensity. The resultant magnetic field produces a rotation of the plane of polarization of light passing in the strain-free flint glass discs so that, during the passage of the current, the shutter becomes relatively transparent and passes about 4 per cent of the incident light, or about 30 million times the amount transmitted with the shutter closed.

A diagram of the functional elements of the shutter and camera system is shown in the sketch at the right. The lens system is adjusted so that an image of the object will come to focus on the photosensitive film. Normally, no light passes through the shutter because the plane of polarization of two of the polarizing elements is at right angles to that of the third. The capacitor is charged by throwing the switch to the right, or charge position; and, when the exposure is to be made, the switch is thrown to the left and discharges through the coil surrounding the shutter. During this discharge, the plane of polarization of the light in the flint discs is partially rotated to allow an image of the subject to appear on the photographic plate or film.

As is well known, when a charged condenser discharges through an inductance in a low-resistance circuit, the discharge current is not a single pulse, as would be most useful for the present application. Instead, an oscillatory current occurs which tends to "open" the shutter on successive alternations of the current flow. Although less light is passed through each successive opening, several exposures may be encountered unless precautions are taken to eliminate such multiple exposure effects. Single pulse operation may be attained by increasing the circuit resistance or by providing a spark gap to damp the discharge.

The condenser for storing energy and the coil surrounding the magneto-optic shutter are designed so as to provide the optimum time for shutter opening, usually between four and 10 microseconds. With an optimum exposure time chosen, it is possible to vary the net exposure by changing the voltage to which the condenser is charged. This alters the intensity of the magnetic field through the coil which, in turn, controls the degree of rotation of the polarized light through the shutter to determine the final amount of light recorded on the film. Voltages of the order of 8,000 volts are used to charge the condenser for existing shutters. Shorter exposure times are possible with higher voltages.



Diagrammatic sketch of the functional elements of the high-speed shutter making use of Faraday's magneto-optic effect.

In ordnance use, the camera is set up with a phototube timing circuit so arranged that light from the explosion triggers the electronic control equipment, producing an accurately timed pulse which actuates the shutter. Photographs are usually made of the luminous discharge of the exploding material, although supplementary flash illumination may be used during the short interval for which the shutter is open. An advantage of the shutter is that light from the explosion may be excluded and the shock waves recorded by silhouette techniques. In either case, electrical circuits can be arranged so that small time delays may be introduced into the shutter circuit, making it possible to have the shutter open for any desired portion of the flash. The possibility of making either normal or silhouette photographs of intensely bright flashes greatly expands the capabilities of the photographic technique for industry.

Mechanism of Steel Hardening

New light on the mechanism by which steel may be hardened comes from recent studies conducted in the Department of Metallurgy. Research conducted under the direction of Professor Morris Cohen, '33, of the Department of Metallurgy, has demonstrated that, in the process which makes steel hard, the atoms of steel can take up new positions even at the extremely low temperatures of liquid helium, –453 degrees F., and the steel, therefore, does not necessarily require sudden quenching at elevated temperatures as has been the practice in the past.

By showing the possible role of extreme cold in the hardening of steel, the Technology studies indicate that steel hardening may take place more completely at low temperatures than at any other. Steel hardening is described as a co-operative, shearlike sliding of many atoms moving in unison, rather than a result of individual movements of the atoms. At extremely low

temperatures, large groups of atoms participate in such sliding motion and are thus transformed from a soft form of steel known as "austenite" to a hard form known as "martensite." In some types of steel the amount of martensite produced was found to be near 100 per cent at the temperature of liquid helium, whereas very little was formed at room temperature. In other steels, hardening did not begin until a temperature of –240 degrees F. was reached. At such reduced temperatures, cold-working is highly effective in increasing hardness of steel.

While the practical advantages to be gained from low-temperature steel hardening will be obvious, the better understanding of the mechanism of steel hardening will be an even more significant result to come from this research. The new theory on steel hardening has made possible, for the first time, quantitative predictions of the behavior of steel treated in specific processes. This, in turn, promises that a more scientific approach may replace "cut and try" methods in future improvements of processing.

In these studies, Benjamin L. Averbach, '47, Assistant Professor of Metallurgy, and Saul A. Kulin, '49, research assistant, have been associated with Professor Cohen. The work has been made possible by the availability of large amounts of liquid helium which stems from the pioneering low-temperature research done a few years ago by Professor Samuel C. Collins of the Department of Mechanical Engineering – research which led to the development of the helium cryostat. The project, which has been sponsored by the Office of Naval Research with the aid of several steelmaking firms, is a concrete example of the co-operation which brings together specialists in various fields of learning for a common attack on scientific and technical problems encountered in research.

Inside Information

Now nearing completion at the Institute is a linear accelerator capable of producing extremely intense x-rays and abundant neutrons, both of which are highly useful for obtaining inside information of the nuclear structure of the atom. Radiation equivalent to that produced by a kilogram of radium can be produced when the machine operates at full power. Like other machines of its type, the linear particle accelerator will be used primarily to yield experimental data which serve to verify or disprove present hypotheses regarding the ultimate structure of matter.

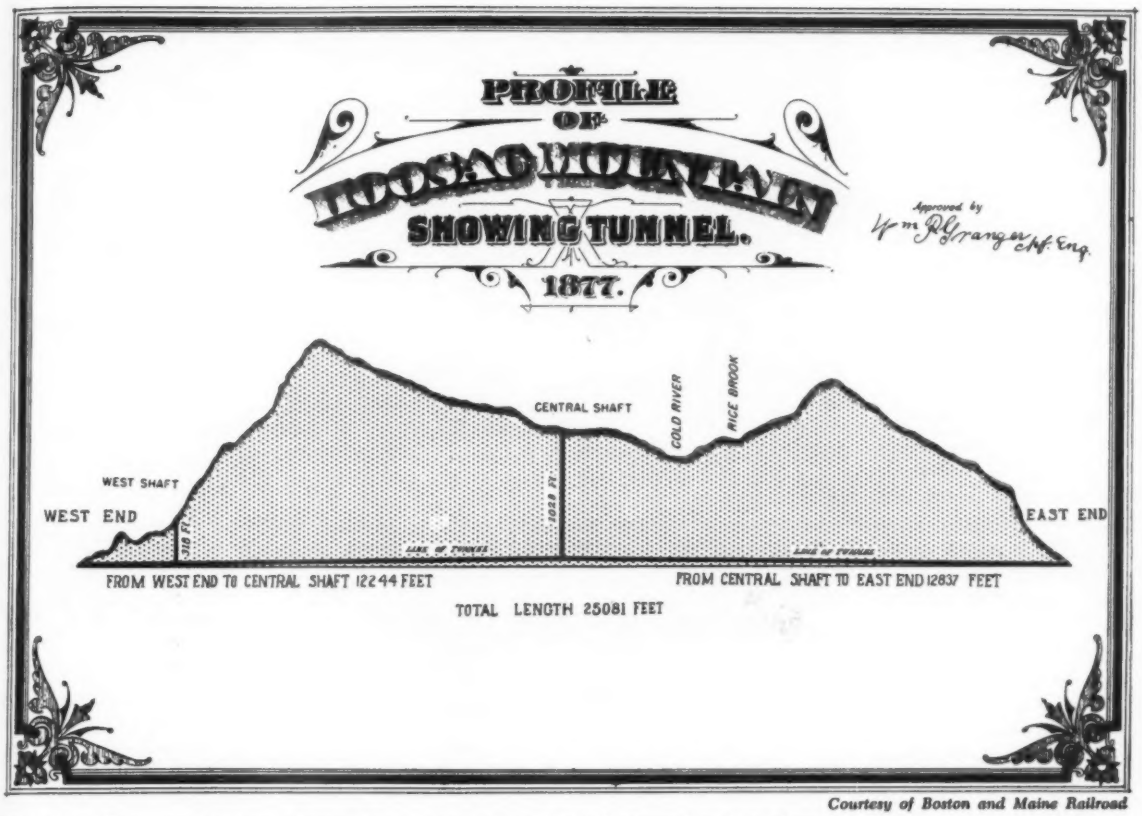
Like the cyclotron and the synchrotron (already in operation at the Institute), and the 12-million-electron-volt Van de Graaff generator (now nearing completion), the linear accelerator is one type of a sizable group of devices for imparting high energy to subatomic particles. It is, in fact, a device for speeding up electrons in a beam to a very high energy, and for producing an intense source of radiation when the electron beam strikes its target. Like these machines, it has its own peculiar advantages and disadvantages. Unlike the Van de Graaff generator, for example, the energy of the electrons accelerated by it is not uniform but spread out over an appreciable range. On the other hand, it requires, by its very design, power sources which are operated only at moderate voltages, thus avoiding the insulation problems of the Van de Graaff generator. While its energy, about 17 million volts, is much lower than that of the synchrotron and no greater than many betatrons now in use, its high-beam intensity should make it suitable for experiments which could not be done with other machines.

The M.I.T. linear accelerator speeds electrons to a very high energy by letting them interact with an extremely high-frequency electric field. In a specially designed cylindrical pipe, or wave guide, properly separated into a succession of cavities, electromagnetic waves are set up, similar to those used in radar. These waves travel with the velocity of light, and if electrons of nearly the same velocity are injected into the wave guide, they travel down the accelerator in phase with the wave. In so doing, they acquire energy from the wave much as a surf rider acquires energy by "skiing" along the leading edge of a water wave.

Prior to their introduction into the wave guide, the electrons are speeded up to 97 per cent of the velocity of light by high voltage produced by a Van de Graaff electrostatic generator. Further energy is imparted to the electrons by the electromagnetic wave produced in the wave guide by 21 magnetrons of the type used to produce radar signals. One of the difficult technical problems of the design of the accelerator was to get all tubes operating in perfect synchronism, a feat which had not previously been attempted. The magnetrons produce 120 pulses of energy per second, each having a duration of about a millionth of a second. During the short periods of operation, the power of output of the magnetron is more than 5,000 kilowatts. The pulses are so short, however, and the periods between pulses comparatively so long, that the average power is in the neighborhood of about five kilowatts.

So far, it has been necessary to operate the accelerator at less than its maximum power output because of the large amount of radiation which is produced. The recent completion of a concrete room with floor, walls, and ceiling three feet thick should provide adequate shielding and reduce radiation to the point where safe operation can be achieved with full beam current. Tests are now being conducted to check the effectiveness of the shielding, and to bring the accelerator gradually up to its full rated beam current.

Construction of the M.I.T. linear accelerator was started soon after World War II, under the auspices of the Research Laboratory of Electronics, under the general supervision of Professor John C. Slater, Head of the Department of Physics. The first two or three years were spent on research and design, and the actual construction has taken several years. The accelerator is now practically ready for use on nuclear experiments, and for this reason it has now been taken over by the Laboratory for Nuclear Science and Engineering. Peter T. Demos, '49, research associate in the Physics Department, is now concerned with its development, and it will be used for nuclear research by him, Isaac Halpern, '48, of the Division of Industrial Coöperation, and several other members of the Nuclear Science Laboratory. Construction has been carried on by funds furnished the two laboratories by the Office of Naval Research, the Signal Corps, the Air Materiel Command, and the Atomic Energy Commission.



Courtesy of Boston and Maine Railroad

The above illustration has been adapted from a poster of 1877. The horizontal scale is about 4,200 feet per inch; vertical scale, about 1,300 feet per inch.

The Blasted Bore

Under Construction for Two and One-Half Decades, the Hoosac Tunnel Now Celebrates Its Centennial

By E. H. CAMERON

One hundred years ago, at the time of the Boston Railroad Jubilee in 1851, the region of New England was said to have "no natural production for export but granite and ice." In other words, it was poor in natural resources and had to live largely by its wits to keep up with the sections of the United States to which Mother Nature had been more kind with her endowments. The Yankee formula, which had already been developed to meet this situation, is simple: The method has worked for generations as the recurring threats to New England prosperity have been met. First, the hard facts of the existing crisis are studied. Next, the future is viewed through the dark glasses of a deep pessimism which is merely to put the fear of God into the hearts of the threatened ones; for hard facts require hard thinking to devise means to overcome the obstacles in the path of New England well-being. In the final step, Yankee ingenuity and audacity join to point a way out, and it is a foregone conclusion that courage and persistence will carry out the program with success. An inspiring example of this fine spirit of Yankee determination lies in the story of the Hoosac Tunnel, which this month is celebrating the 100th anniversary of its inception.

On January 7, 1851, the directors of an ambitious engineering venture voted to break ground the next day on a railroad that was to connect Troy, N.Y., and Greenfield, Mass. Their railroad would provide New England with an easy and direct connection with the lines leading toward the American Great West, with its promise of fabulous riches – precious ores, farm products, and timber. The success of this railroad would depend upon the driving of a tunnel through the talcose slate rock of the Hoosac Mountain, in the extreme northwesterly corner of Massachusetts. It would be several times longer than the longest tunnel in the world – nearly five miles long – and would be known as the Hoosac Tunnel.

This bold move was made in the heyday of New England maritime prosperity, when its venturesome

clipper ships advertised the high quality of American enterprise in the far corners of the earth. Along with the Yankee willingness, to back with hard-earned dollars the heavy risks of the well-established maritime industry, went a foresight that told when to undertake the hazards of newer ventures, so long as they appeared within the powers of Yankee ingenuity to finance and construct. Foresight must have warned Boston financiers that the aggregate profits from their maritime investments might look small when compared with the gains that could be realized from funds invested in the young American railroad industry. As evidence of this feeling, in the year when the finest of the clipper ships, the *Flying Cloud*, was launched in Boston, there occurred both the start of the Troy and Greenfield Railroad and the celebration of the Great Boston Railroad Jubilee of 1851. At this brave festival, Daniel Webster and other statesmen, including the President of the United States, had extolled the impressive New England progress since the American railroad industry had started, two decades earlier. Further expansion of the railroad systems of New England was limited by a severe geological handicap.

Mrs Bella C Landauer Collection, New York Historical Society

The Fitchburg Railroad Company, which inherited the tunnel from the Troy and Greenfield Railroad in 1887, lost no time in exploiting the old claims of its merits as a route to the American Great West. The little boiler of the westbound locomotive seems designed to be merely a support on which to mount the huge smokestack (bellmouthed to catch sparks from the wood-burning firebox), the cowcatcher, and the headlight. The keystone date identifies this as the west portal. The east portal is dated 1877.

The locomotive engines of 100 years ago were puny, and the Hoosac Range which blocked off the Massachusetts westerly boundary was high and steep.[1] The hard grades and sharp curves were a severe tax on the little Western Railroad (now the Boston and Albany) which was the only New England railroad to serve directly the region west of the Hudson River. The impoverished Western Railroad made a poor New England weapon in the battle of the easterly sections of America for the trade of the agriculturally rich Ohio country, and of the Great West beyond the Mississippi River. Already, the rivals of New England for this tempting trade had made effective moves toward securing it, via railroad lines which later became known as the Baltimore and Ohio, the New York Central, and the Pennsylvania. Of course, a heavy volume of freight was already being handled by the Erie Canal–Hudson River route. As has so often happened in later generations, canny New England felt that it was slipping: It was falling behind in the race for the profits to come from the development of the wonderful American Great West.

The answer to the dilemma came from an incident of a generation earlier, during the era when canals were the accepted means of traffic with the advancing westerly frontier of America. Stirred by the start of construction of the Erie Canal, Loammi Baldwin, a Yankee engineering promoter who has been called the father of American civil engineering, had then proposed (1825) to extend the canal system of New England by a canal through the Hoosac Mountain. "Why, sir," he would exclaim, "it seems as if the finger of Providence had marked out this route from the East to the West." On the line of the never built canal tunnel of Baldwin, through the Hoosac Mountain, the route of the Hoosac Tunnel was laid down. The petition for legislation for the first loan toward the construction of the railroad tunnel at this site[2] was based on Baldwin's old canal-tunnel estimate of cost.

In the long, seriocomic political controversy that went on during its construction, the Hoosac Tunnel became a joke, albeit a jest of macabre import when one considers its brutally high fatality record. Coincident with a progress that lists the loss of one human life for each 125 to 250 feet of tunnel, according to which record is accepted as correct, went a political battle that became a saga of political strife, for almost all of its cost had to be paid for by the State of Massachusetts. During this battle, the thrifty legislators on Beacon Hill had to decide whether those who called for more and still more tunnel funds were men of vision or were just visionary. In a series of bitter pamphlets, the tunnel was dubbed the "Great Bore" by a Massachusetts man, of a family that later begat a distinguished governor of the old Bay State. On the other side, substantial encouragement and strong support was given during the construction of the tunnel

[1] The larger locomotives of the day weighed only 30 tons, as compared with the modern "Big Boy" of the Union Pacific Railroad weighing 600 tons.

[2] A featured advantage of the Troy and Greenfield Railroad over the Western Railroad was the fact that it would traverse a region of vast forests, with wood available at $1.50 a cord, whereas the wood fuel supply for the locomotive engines of the Western Railroad was becoming exhausted, and cost $5.00 to $6.00 a cord.

by many a loyal New Englander.[3] As the years dragged on, friends and foes alike began to wonder if the tunnel ever would be finished. Even the cheerful Oliver Wendell Holmes became doubtful. Writing in *The Autocrat of the Breakfast Table*, Holmes expressed the opinion that the world could end:

"When the first locomotive's wheel
Rolls through the Hoosac Tunnel's Bore."

Twenty-five years after the start of the tunnel, the dream of the promoters of the ill-fated Troy and Greenfield Railroad came true, when the tunnel was opened for regular passenger traffic in the centennial year of the United States, 1876.

The Old Methods (1851–1861)

The 25-year construction program of the Hoosac Tunnel (1851–1876) logically divides into four periods, a review of which indicates the progress from the age-old mining methods of subterranean excavation to the faster and more efficient methods required to complete a project of such magnitude within practical limits of time and cost. There was thus a 10-year period of little progress under private contracts, succeeded by a two-year period, during which work was held up, as past mistakes were investigated and data collected on more successful methods used elsewhere. A period of six years of activity under state control followed, during which more effective methods were developed. The final period of seven years under a private contractor, using the improved methods, drove the remaining 63 per cent of the tunnel to success. Each period, either by its failures or successes, helped to develop practical methods of tunnel construction, which form the basis of those of today. Particularly, the modern construction and mining industries owe a great debt to those who built the tunnel, for their trial-and-error work in the use of compressed air and the blasting of rock by nitroglycerin, in the period when Alfred Nobel was developing dynamite – a safer form of this new and mysterious explosive.

In this first period of strong doubt whether the tunnel was feasible, scant records of experience existed for carrying on the various steps of a tunnel project of such magnitude: the drilling of the rock; the charging and detonation of the explosive to blast it away; the disposal of the spoil; ventilation; drainage; and illumination. The rock was removed at the start by one-jack and double-jack hand-drilling[4] of the holes in which the black gunpowder charges were inserted. The charges were set off by fuses, ignited by candles.

Years earlier, Isaac M. Singer, of sewing machine fame, had built several steam-operated, vertical rock drills which were used on the Illinois-Michigan Canal in 1838. Two years before the start of the tunnel (1849), Joseph J. Couch, of Philadelphia, had patented a cumbersome percussion drill, driven by steam. In the very year of the beginning of the tunnel, what seems to be the basic patent of a mechanical rock drill, which should simulate hand-drilling methods most practically, was granted to J. W. Fowle, an assistant of Couch. Fowle's machine made the cutting tool an extension of the piston, rotation being actuated by a ratchet-and-pawl device. Several other semipractical rock drills were patented during the next few years, while hand methods of drilling continued on the slaty rock and quartz seams of the tunnel. It would be several years before a truly practical mechanical rock drill was devised.

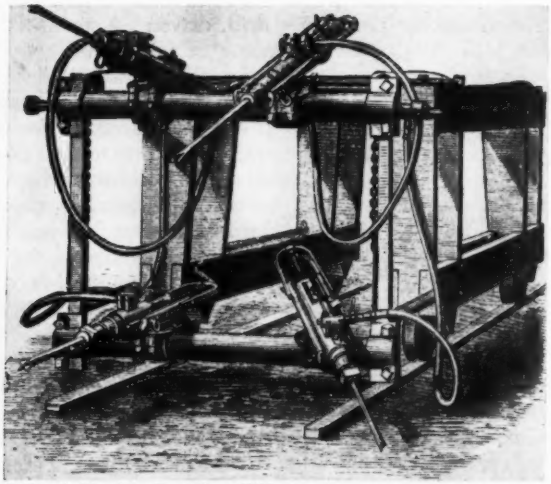
A fortunate feature of the geology of the site lay in the fact that the grade of track at the west end could be made the same as that of the east end; and that the Cold River Valley, near the center of the tunnel, was at a low enough elevation to allow the practical construction of a central shaft from the surface down to the tunnel. Two advantages went with these features: first, with the center of the tunnel established at a higher level than the ends, water which seeped through the seams of the rock strata could drain naturally to the east and west portals, avoiding high pumping charges; second, the tunnel could be worked from four headings instead of two.

Legislators who considered a state loan paid close attention to the report on the geology of the Hoosac Tunnel by Edward Hitchcock, who was state geologist of Massachusetts, and president of Amherst College – a man highly respected in Europe and in America for his scientific knowledge in the day when American science was in its infancy. He called the tunnel feasible to construct. Hitchcock's prediction of rock conditions was verified by later geologists, who found a limestone formation near the west portal, changing

This view at the west portal was taken when the heading had been advanced 4,500 feet. The westerly section of the tunnel proved most difficult, due to the soft rock and water condition encountered. Of the tunnel's total length of 25,081 feet, 7,573 feet were brick, arched with six rings, as shown.

[3] Most notably Otis Clapp, the pharmacist, one of the first members of the M.I.T. Corporation.

[4] "A double-hand hammer or 'double-jack' is gripped and swung with two hands. This type of drilling calls for two men, one to strike the drill steel and the other to hold it in the hole and to turn it after each blow. In single-hand drilling, one man both strikes and holds the steel." – *Compressed Air Magazine*, January, 1938.



Scribner's Monthly, *December, 1870*

A contemporary Burleigh drill used on the Sutro Tunnel between 1874 and 1878 was described in Compressed Air Magazine, *January, 1938, as follows: "This machine is 6 feet long, weighs 550 pounds, has a 14-inch stroke, and can drill a 1⅞ inch hole at the rate of 1.22 inches per minute when operated with air at 60 to 70 pounds pressure. The piston is 4¾ inches in diameter. The complete piston assembly, including the chuck, weighs 125 pounds and reciprocates at the rate of 300 blows per minute."*

in an easterly direction to mica, slate with quartz veins, and with much feldspar. A hard gneiss occurred near the center of the mountain, changing near the east portal to talcose slate. For the easterly portion of the tunnel, the dip of the rock strata was near enough the vertical to avoid the danger of falling rock; hence lining was unnecessary. The dip is quite flat in the westerly portion, requiring brick arching for about 7,600 feet of tunnel. Ground water leakage through the seams proved to be considerable, and the damp walls proved an ever present hazard to those who handled the crude electrical blasting apparatus.

Early in the program came the "boring machine" experiments. Unlike a rock drill, which drives holes to receive explosive charges, the boring machine was supposed to cut, by the impact of rotary cutters, a circular groove, 13 inches wide by 24 feet diameter. The rock within the groove was to be broken out either by blasting or by wedges. This $25,000 machine was unsuccessful and was abandoned. At this stage, spoil was removed by mule cars; drainage flowed via ditches to the portals. Lighting was by candles and open-flame oil lamps. There was little ventilation.

As evidence of how impracticable the tunnel was proving to be, the doubters pointed to the difficulties encountered. Their criticism focused on the record of the first contractor to make an organized start on the work: Herman Haupt, a graduate of West Point, with a previous wide experience in private railroad construction. In the voluminous files of the political history of the tunnel, Haupt's name appears most frequently. Thrown off the tunnel job in 1861, the year of the start of the Civil War, Haupt went back to the U.S. Army and was placed in charge of Construction and Transportation of U.S. Military Railroads. His subsequent record in one of General Grant's campaigns was so impressive that he was offered a commission of Brigadier General of U.S. Volunteers. Highly endorsed by reputable men, he was accused of unethical practices by men of equal note.[5] The facts of the case appear to be that he failed at the Hoosac Tunnel because of the limited knowledge of tunnel work in the earlier period of its construction and that other, perhaps more talented, engineers were able to take lessons from his failures and succeed with the successful methods at the Mont Cenis Tunnel in Europe.

Started in the year when *Uncle Tom's Cabin* first appeared in print,[6] this period of the tunnel construction

[5] A collector's item is Haupt's *General Theory of Bridge Construction* which was published in 1851.

[6] First published as a serial in *The National Era*, Washington, in 1851 and 1852.

The steadiest men were selected for work in the converting room, and each moved like clockwork. After the various operations were completed, the floors were swilled with water so as to keep them scrupulously clean of nitroglycerin, which when stepped on might explode violently. Despite all precautions, a magazine at the east portal blew up, killing the three miners who went that morning to prepare the nitroglycerin for the day's use. It was reasoned that a man had dropped a hot coal on the wood floor at the heater. These accidents occurred before the then novel method of steam heating was adopted.

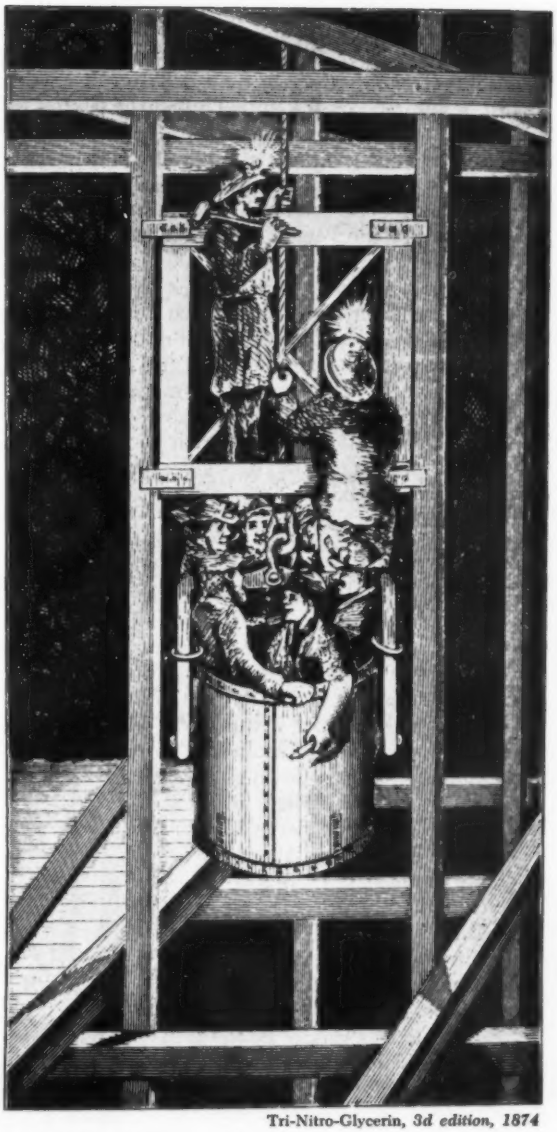
Tri-Nitro-Glycerin, *3d edition, 1874*

witnessed the increasing strength of the abolitionists, whom the famous novel on slavery inspired; continued through the presidencies of Fillmore, Pierce, and Buchanan during which the slavery controversy surged to its climax. Lincoln was elected President and the Civil War started with the firing on Fort Sumter. The tunnel could not be called a military necessity, as was the case with the Pacific railroads. Dissatisfaction with the methods of Haupt was so bitter, and the war needs were so great, that work on the tunnel was stopped in the year 1861.

Period of Taking Stock (1861–1863)

The young American railroad industry had now reached sturdy proportions. Throughout the East were many factories that made locomotives, cars, iron rails, and track fittings, and the total mileage of operated roads had increased threefold since the start of the tunnel (10,982 miles in 1851 to 31,286 miles in 1861). In its first campaign, the Republican party sponsored the construction of a railroad to the Pacific Coast, an inspiring bit of news to the proponents of the Hoosac Tunnel. As they considered the poor record of tunnel progress to date, they could see more promising developments in the search for practical mechanical drills and a more powerful explosive. They learned, however, that their tunnel could no longer be called the longest in the world.[7] Now under construction at Mont Cenis was a tunnel that would be nearly eight miles long, near the famous pass across the Franco-Italian Alps frontier, where the Emperor Napoleon had built a carriage road years earlier. (The Mont Cenis Tunnel was to be completed five years earlier than the Hoosac Tunnel.) At this tunnel, European engineers had found that air could be condensed and the compressed air transmitted long distances. Machines had been invented in which this compressed air, like steam, drove pistons to operate cutting tools, which drilled the holes for charges of gunpowder. The Hoosac Tunnel authorities sent competent Charles S. Storrow to investigate this successful use of compressed air on the Mont Cenis Tunnel, whose report is a fine model for modern engineers. James Laurie, the first President of the young American Society of Civil Engineers, was called in at this time for advice. Laurie compared the cost of shipments to the West via the tunnel with the costs via the several routes with which it would compete. He reviewed the Storrow report, and his conclusion stated that, of course, the tunnel was feasible to construct; but like any shrewd Scotchman, he told the Commission that it was up to them to decide if it would pay off. Another consulting engineer was called in at this period – Benjamin H. Latrobe,[8] chief engineer of the Baltimore and Ohio Railroad, who had extensive experience on the shorter tunnels of that railroad. The highlight of the Latrobe report was its statement of an obvious axiom of rock-tunnel procedure: "The boring machine which had been tried on the Hoosac Tunnel was an example of misdirected mechanical ingenuity," he said. "The explosive must do the work, not mechanical devices."

During a dark period of the Civil War, John A. Andrew, the famous war governor of Massachusetts, took time to review these reports. His message to the legislature said: "Considering the benefits . . . to . . . City and State, we are of the opinion that the work should be undertaken by the Commonwealth, and completed as early as it can be, with due regard to economy." This endorsement by Andrew saved the Hoosac Tunnel, but he did not live to see its completion.



Tri-Nitro-Glycerin, *3d edition, 1874*

Unlike their European confreres who were constructing the Mont Cenis Tunnel under the lofty Alps, the builders of the Hoosac Tunnel found it practicable to excavate a shaft near the center, which allowed them to work four headings simultaneously. The 62 wooden floors of the 1,028-foot-deep shaft were connected by ladders, but the Irish and Cornish miners would, of course, ride the hoist; one is shown carrying a candle.

[7] Today, the Hoosac Tunnel is listed as the fourth longest tunnel in North America. See *Railroad Magazine*, June, 1946.

[8] Latrobe's father, Benjamin Henry Latrobe, "constructed the south wing of the Capitol (at Washington) . . . resigning his post as Architect of the Capitol in 1817." – Washington *Star*.

Period of Development (1863–1869)

The spirit of optimism following the Battle of Gettysburg in July, 1863, undoubtedly influenced the Massachusetts authorities in their decision that work should be resumed on the tunnel under the control of a State Commission (October, 1863). The war had caused a tremendous industrial expansion in the northern states which would continue, it was hoped, after the war should end. Ground had been broken on the westerly end of the Pacific Railroads at Sacramento, Calif., and in two months a start would be made on the easterly end at Omaha, Neb. It was important that New England should be ready, when peace came, to get its share of the trade with the Great West, via the Pacific Railroads. The completion of the Hoosac Tunnel seemed still more necessary, and trials must be made of the two powerful agencies which had been used elsewhere: compressed air with good success at the Mont Cenis Tunnel, and nitroglycerin for blasting, with promise of success, in certain European countries and in the oil fields of Pennsylvania.

In their enthusiastic review of the success of compressed air at Mont Cenis, both Laurie and Latrobe were confident that American ingenuity would produce still better methods. Soon this optimism was justified when Charles Burleigh of Fitchburg, Mass., with his two assistants, patented rock-drilling equipment which proved to be practical. Of the 40 Burleigh drills soon in use in the tunnel, it was said: "Mr. Burleigh's invention has several 'weakest spots,' and often breaks down but never wears out." Burleigh also built (1866) the first large air compressor of practical value to originate in the United States — several of these supplying compressed air at a pressure of six atmospheres, at the tunnel. A rock-filled, timber crib dam across the Deerfield River was built during this period to supply power to drive the compressors at the east portal. During the dry summer months here, and at the central shaft and west portal, steam-driven compressors were used.

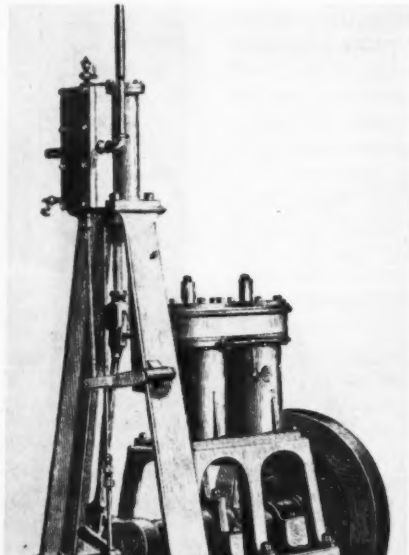
The accuracy of the tunnel alignment and the ingenuity of the methods used were notable. The aboveground line was marked by four iron poles set in masonry: two on each mountain peak between the portals, and two (backsights) across the Deerfield and Hoosac rivers, respectively. From these exterior signal points, the interior tunnel lines from each portal toward the central shaft were laid down. At the central shaft, the exterior line was transferred to tunnel grade by two 15-pound plummets, 23 feet apart suspended in buckets of water by wires, 1,000 feet in length. The scope of this article does not permit a description of the cleverly designed instruments invented for this procedure, or the numerous adjustments required under summer and winter conditions before an accurate line was located for driving the tunnel from the shaft toward the two portals. That this 23-foot-long line was accurate is attested by the fact that, when extended over 1,500 feet to the east, it missed the line of the east portal heading by only $\frac{5}{16}$ of an inch. The deviation of the line, extending over 2,000 feet westerly, missed the line of the west portal heading by $\frac{9}{16}$ of an inch.

Toward the end of this period, nitroglycerin was first used. As an expert in the use of this powerful explosive, George M. Mowbray,[9] "operative chemist," was called from the oil fields of Pennsylvania to the tunnel by Thomas Doane, chief engineer. The sinister reputation of nitroglycerin at this time is indicated by the following incidents in its pioneer transportation and handling.

Tempted by the promise of quick profits, both in the gold mines of California and the oil fields of Pennsylvania, a European gentleman had brought to New York a sample of glonoin oil, a form of nitroglycerin, hoping to interest American promoters in its use. The shrewd clerk of his hotel on Greenwich Street had held the package of glonoin oil for security, when it became evident that his guest was unsuccessful in his efforts to interest American investors. When the package began to emit yellow fumes, the clerk rushed to the door and tossed it into the street. Although no one was killed in the ensuing explosion, all windows within a radius of 100 yards were shattered. Forty-seven people had been killed when a shipment of nitroglycerin in the iron steamship *European*, en route from Europe to San Francisco, had exploded at Aspinwall, now Colón, Panama. Eight persons had died in the explosion of a Wells Fargo Shipment of nitroglycerin from Hamburg, Germany. Nitroglycerin was in bad repute in America; Germany prohibited its use, and England allowed its use only after strict limitations.

The ensuing success of the tunnel experiments with nitroglycerin made its adoption attractive. All concerned realized that rigid precautions would be needed in its use if casualties were to be kept to a minimum. Mowbray was selected to devise, not only methods for its use, but for its manufacture on the site, for no common carrier would ac-

(*Continued on page 160*)



Scribner's Monthly, *December, 1870*

This rare woodcut shows a steam-driven compressor, used at the west portal, central shaft, and the east portal when the river was too low to supply hydraulic power. It is not clear whether the compressor is two-stage, or if the two air cylinders operated at the same pressure. (Pressures were 90 pounds at the plant, and about 60 pounds at the drills.)

[9] In Pennsylvania, Mowbray had worked with Edwin L. Drake, who drove the first oil well near Titusville, Pa.

The Unchangeable Ship

A Review of Several Unusual and Interesting Ship Designs

Reminds Us That the Basic Ship Shape Has Remained

Essentially Unchanged through the Ages

By WILLY LEY

THERE have been many changes in ocean conveyances since Leif Ericson sailed to Vinland not quite a thousand years ago. His ship was made of wood; ours are of steel. The Vikings may have used thongs, dowels, or nails to hold their ships together; we use rivets and welding. They traveled under sail and with muscle power if the wind were wrong or lacking; we have steam turbines and Diesel engines. The Vikings froze in the open air; we have heated cabins. They were isolated when at sea; we have radio communication. We travel as great a distance per day as they did per week, provided they had favorable conditions. In regard to size, we should consider their ships a bit small for lifeboats. But with all these changes the basic shape of the ship remained the same.

This statement on basic ship design is not intended to refer to the fine points of hull shape and to such design problems as external or internal keel, flat or round bottom. Much of that is determined by the use to which the ship is to be put (passenger liner, vehicle ferry, freighter, combat vessel) or by the type (lake, river, or high seas) and to some extent also by the overall size. But it does have reference to the general shape; it refers to whether the bow is pointed or not, as well as the stern, and applies to ships whose ratio of length to beam (width) is 3.5 to 1 or more. The general "ship shape" has remained unchanged since it was first devised, and all attempts to do away with it have found an inglorious and usually very quiet end. A recounting of a number of attempts to introduce radical departures emphasizes this point.

Beginning with the most impractical idea of all, it may be reported that, about 1860, a number of men in England founded the Jointed Ship Company, Ltd. Positive that freight shipping by sea could profit from the example of the railroad train, the inventor for this company proposed to build a ship which was literally hinged together of independent units. The purpose was not so much to increase seaworthiness or speed or anything like that; the company merely wanted to produce a commercially superior type of freight vessel. Why should the whole ship be delayed in port if only one section were to be loaded or unloaded? Why not disconnect the whole section, proceed without it, and pick it up again later? The proposed jointed ship was actually built in 1863, and was christened the *Connector*. It consisted of three sections only: the bow section (of orthodox shape); the detachable center section (square at both ends); and the stern section (also of orthodox shape). Each section had a lifeboat and a mast. The stern section also had a steam engine. Of course more than one center section was planned for later use. The first ship was merely to prove the superiority of the idea.

A trial trip was made on a day which happened to have fine weather. The disconnecting of the center section was demonstrated, and then a party of engineers and Navy officers were taken for a ride on the shortened ship and served dinner at sea. For reasons easy to imagine, contemporary comment seems to have consisted of vague generalities only. Any old salt, or any engineer, hearing the statement that neither a heavy sea nor even running aground would break the ship's back, must have asked himself about the pins which held the sections together. As far as one can gather, the *Connector* made a total of two trial runs. What happened to it afterwards is described nowhere. Presumably, the Jointed Ship Company, Inc. became disjointed quickly, and every investor decided that silence was at least face-saving, if not golden.

If the *Connector* were decidedly absurd, one could not be so sure from the outset about the next attempt to abandon the traditional and proven ship shape. The reasons for that next attempt were not commercial but military. Just a year earlier than the *Connector* episode, a strange-looking craft had been launched in America. This was Ericsson's *Monitor* – the famous ship being commonly described as a "Yankee cheese box on a raft." While the original *Monitor* did not actually sweep all Confederates from the seas by itself naval experts quickly saw that such monitors might be a useful addition to fighting fleets. Unfortunately, the single turret sometimes got stuck and might do so even more frequently because of enemy action. Then, too, the monitors were no steady gun platforms, but of course nothing else was either.

Vice-Admiral Popoff of the Imperial Russian Navy thought that he had the answer to both difficulties with which the *Monitor* was afflicted. His solution amounted to making the "cheese box" float by itself. He drew plans for a circular monitor with two heavy guns in the middle, two funnels flanking the guns, and a few small and low structures scattered around. There was even a small mast, presumably for flying the flag, for it could not have had any other use. Vice-Admiral Popoff's plans were approved by the Czar of All the Russians, the treasurer surrendered the necessary cash with a bare minimum of the usual com-

plaints, and two such vessels were built – one in 1873, the other in 1875. The first was called the *Novgorod;* the second bore the inventor's name. The Russians called these vessels "popoffkas." The two popoffkas were not sister ships, and the differences between them can best be shown in a short table:

	Novgorod	*Vice-Admiral Popoff*
Year of launching	1873	1875
Guns, 2	11-inch	12-inch
Barbette armor	7 inches	9 inches
Deck armor	1 inch	3 inches
Engine power	2,000 horsepower	3,066 horsepower
Screws	6	4
Speed	6 knots	8.5 knots
Draft	13 feet	13 feet
Diameter	121 feet	130 feet

The directing of the guns was done by aiming the ship. Unfortunately the results of target practice, which certainly must have been exceedingly interesting, were never published. The popoffkas did create the desired steady gun platform, but that was all. If there was even a mild sea running, the decks were awash. And if there was a heavier sea running, something else happened: the circular ship, with its flat bottom, would not "ride" a sea; it was just battered by the waves. The ship was strong enough to take such battering but the crews were not.

Naval men everywhere were not a little curious when the Russo-Turkish War broke out four years after the popoffkas were ready. But they never learned how the circular warships performed in combat, as both of them were moored in Odessa Harbor. What naval men did learn, after a suitable interval of time, was that the popoffkas had had an interesting adventure earlier. They had traveled up the Dnieper River until the commander (Popoff himself had died in the meantime) decided to turn them around and go back to the sea again. During the maneuver they were caught by the current, and nothing their commanders or crews could do brought them under control again. The current not only swept them down river, but it also whirled them around and around until everybody aboard was too sick to care much what happened.

In view of these events it sounds doubly strange that there was a successor to the popoffkas, but there was. The Czar, Alexander II, had watched their progress and adventures, presumably by reading carefully worded official reports. There was one fact which stuck in his mind: the popoffkas did not roll. That was the kind of ship he wanted – a vessel on which one would not become seasick in front of one's subjects. Since he was Czar, he could have such a ship built for his personal use. But he had another wish: his yacht should not look like a warship; it should look like a yacht. The designer solved the problem by taking a yacht of customary lines, but of most extraordinary beam, and building it on top of a modified popoffka which was not quite circular. The resulting monstrosity was 235 feet long, had a beam of about 155 feet, and a draft of only 6½ feet.

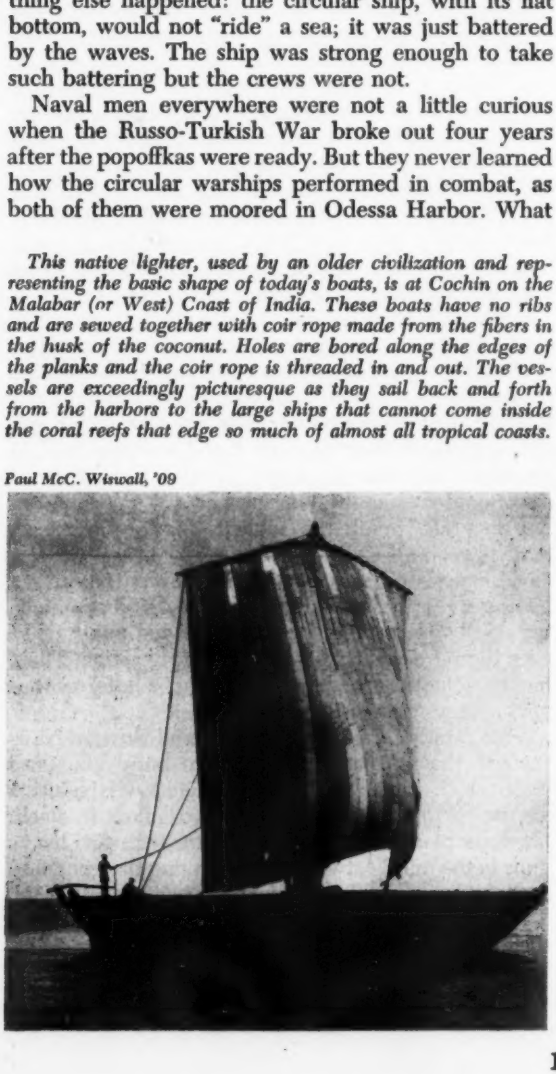
The name of this unusual vessel became *Livadia,* which was also the name of the Czar's summer palace in the Crimea. But the Livadia was not built in Russia; it was ordered from the firm of John Elder and Company in Scotland. Scottish businessmen do not laugh at a customer when he is present, most especially not at an indubitably solvent customer. John Elder and Company merely made sure that the price was right and that all the specifications were met. The speed had to be 14 knots or John Elder and Company would not be able to make the sale. They made sure that the speed was almost 16 knots. The Russians accepted her after a fast trial run in calm weather.

Then the *Livadia* was to be taken to the Black Sea. The Bay of Biscay was stormy as usual. As promised, the *Livadia* did not roll – or only very slightly. However, the waves, acting on a flat bottom of such size, battered a few watertight compartments into being no longer watertight. By the time the harbor of El Ferrol (northern Spain) was reached, the crew was almost completely exhausted. In the end, however, the Black Sea was reached and the *Livadia* did serve as the imperial yacht and, after the Russian revolution, became a repair ship for the Russian Navy. She was finally broken up in 1926. She was afloat longer than most ships, but she was not an improvement.

Now the main reason for designing both the popoffkas and the *Livadia* had been the desire to have a steady ship – a ship on which one would not get seasick. Sir Henry Bessemer, the famous inventor, who was so susceptible to seasickness that he needed more than 24 hours to recover from a trip across the English Channel, tried to solve this problem by having the saloon of the ship suspended and equipped with counteracting hydraulic cylinders. Such a ship was actually built (Sir Henry lost $170,000 in the ven-

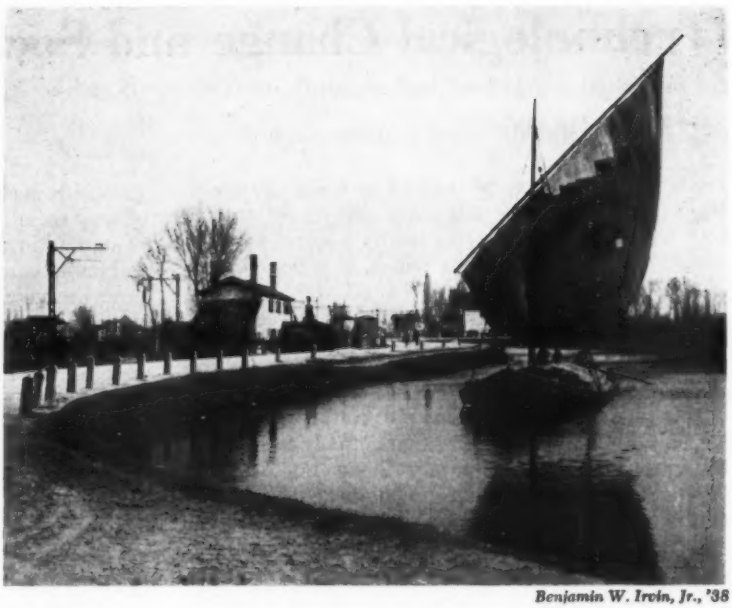
This native lighter, used by an older civilization and representing the basic shape of today's boats, is at Cochin on the Malabar (or West) Coast of India. These boats have no ribs and are sewed together with coir rope made from the fibers in the husk of the coconut. Holes are bored along the edges of the planks and the coir rope is threaded in and out. The vessels are exceedingly picturesque as they sail back and forth from the harbors to the large ships that cannot come inside the coral reefs that edge so much of almost all tropical coasts.

Paul McC. Wiswall, '09



ture) and was singularly unsuccessful; but since this was essentially an inboard improvement it does not interest us here. That the *Bessemer* handled poorly and had a pronounced tendency to run into piers, both French and English, was probably due to her excessive length, and may be attributed as a mistake in design rather than a premeditated change.

But there existed one more possibility for ameliorating a ship's motion: the twin-hulled ship, usually called the catamaran. It was actually a leftover from the days of the old raft—faithfully, and usefully, preserved too in the outrigger canoes of the South Seas. However, the invention of the twin-hulled craft was indubitably made independently quite often. Such craft is occasionally mentioned in classical antiquity, Mediterranean region. It was also used in the South Seas; for example, by the Maori, before the white race arrived there.



Benjamin W. Irvin, Jr., '38

This boat, whose curve of sail balances that of the Brenta Canal water line near Venice, Italy, has a broadness of beam which could have been the basis of some of our World War II ships — perhaps even the LST's!

Of recent ships of this type the first one seems to have been a catamaran built by Sir William Petty in 1663. It was used for some time between Dublin and Holyhead until it was lost in a storm. Petty's ship was built of wood, but the next catamaran which was actually used was made of iron. Invented by one Peter Borrie, she was appropriately named *Gemini*, after the constellation of the Twins, and was built in 1850. She consisted of two rather long hulls, which were 157 feet long with a beam of 8½ feet. The two hulls were placed 9½ feet apart and then joined by a deck which had, consequently, a width of 26½ feet. Propulsion was by means of a paddle wheel between the two hulls, driven by reversible engines — a fairly new idea at that time. The *Gemini* attracted a lot of attention, but as a business venture she was not successful.

The next large twin hull was built by an English captain named Dicey who had spent many years of his life in Calcutta where he had been impressed with the stability of native outrigger canoes. After returning to England, he designed a twin-hulled steamer (influenced to some extent, no doubt, by the *Gemini*) for service between England and France. Expecting that the vessel might be slower than a single-hulled ship, the designer paid special attention to luxurious cabins, a spacious main lounge which was called a "saloon," and to passenger comfort generally.

The ship was put into service in 1874 and bore the name *Castalia*. She was 290 feet long with an over-all width (the term "beam" may be wrong when applied to a catamaran) of 60 feet. Her bridge was about in the middle, atop the main saloon. Her four funnels were placed in two pairs and propulsion was by two paddle wheels between the hulls. A total of 1,000 passengers could be accommodated. As for contemporary reaction to the ship, quoted below is a clipping from the London *Times* during the period when she was still news:

Returning from our autumnal tour, we determined to give the *Castalia* a trial. The weather was unusually boisterous; at Calais it was difficult to stand against the gust of wind which swept across the pier. Outside, the sea ran high, and the usual discomforts of the passage presented themselves to us. The *Castalia*, when she left the pier, seemed to glide to the turbulent waters outside. For a moment it puzzled one to find the deck as firm and level as a dinner table, and yet waves breaking all around. We performed the passage to Dover in about two and a quarter hours; the motion was very slight indeed, about as much as in the ordinary steamers after they get within the harbor of Dover or Calais . . . every few minutes there was one single roll of about three degrees. There was no tremulous motion from the paddles. I explored the saloons for indications of straining, but found none; the surface of the paint was without a shadow of a crack, and throughout the passage there was no creaking noise. When we arrived in Dover the decks before and aft of the funnels were as dry as when we left Calais. The sea was enough to try the regular steamers, but on board the *Castalia* children were playing about, every one was perfectly comfortable, and I can safely state that it was the first time I ever crossed the Channel without seeing a sign of seasickness.

As this narrative shows, the *Castalia* fulfilled many of the hopes of her designer and her investors. She had only one drawback: she was slow. The advertised speed of 15 knots was never reached; on the average, she traveled at about two thirds of that speed. The reason probably was that the second paddle wheel, situated in the space between the two hulls behind the first, exerted drag instead of helping.

Since the *Castalia* of 1874, and a catamaran-like ship named *Vulkan*, with which the Imperial German Navy experimented before World War I, there has been a lack of interest in twin-hulled ships — now

(*Concluded on page 174*)

Technological Change and Social Policy

By PAUL MEADOWS

Social policy may be defined as a self-conscious search for a more adequate adjustment to our way of life. It is, in other words, a search for new physical or social inventions which, it is hoped, will make living more pleasant and comfortable. In any changing culture it is an inevitable and ceaseless search, but in a changing technological culture, such as that of the United States, it is an imperative for survival.

The rule of modern industrial culture is one of mechanization, for mechanization not only transforms the surfaces of contemporary living but stirs its depths. Modern people have encountered (and have deliberately sought to encounter) the machine in every area of their existence. An illuminating discussion on this fact is presented by Sigfried Giedion in *Mechanization Takes Command.*[1] Industrial people have turned to machine technology as a new, a modern, methodology of social adjustment.

Unhappily, the fundamental equilibrium which may be established at any one time in a given system of techniques is precarious and momentary. Innovations seem to start chain reactions of change in many seemingly unrelated areas of social living, and thus new and unexpected adjustments become necessary. First of all, then, the need for social policy arises from the functional interdependence of technological inventions.

Problems of Interrelated Change

Students of modern technology are deeply impressed by the manner in which inventions in one area of modern life are linked with inventions in other areas. Indeed, this technological symbiosis, or mutual dependence, lies at the very root of the general concern with the problem of technology and social policy. Technology itself is not merely a mode of social adjustment; even more significantly, it is a major cause of new social adjustments. In a most thorough study of agricultural technology and social change, an interbureau committee of the Federal government suggests this very point as follows: "Scientific advances in agriculture constantly release labor at a time when employment opportunities are no longer open in urban industry. . . . Lacking other alternatives, the surplus hired men of agriculture swell the ranks of migratory farm workers, apply for direct relief, or find some shelter in subsistence farming, too often in the poorer localities."[2]

Sociologists Ogburn and Nimkoff have suggested a classification of sequences and concomitant variations of technology and society which summarizes these problems of interrelated change: (1) A major material invention may have immediate multiple effects. For example, radio, and now television, exert influences on recreation, entertainment, transportation, education, religion, business, government, and so on. (2) A single invention may have a long series of consequences flowing from it. New forms of labor and new class relationships evolved as a result of the invention of the cotton gin which made possible new industries, new clothing and different styles, and ultimately changed our conception of manufacturing. (3) A given social condition may itself represent the net result of a number of converging inventions. We may cite the way in which the declining birth rate is linked to the factory system, changing occupational patterns, smaller homes, greater individual mobility, and so on. (4) A cluster of inventions may have far-reaching derivative effects, such as are represented by the interrelationships between atomic energy conversion and medicine, power generation, international organization, military strategy and defense. (5) Finally, social inventions may require physical inventions for their facilitation or control. For example, modern national defense and military programs could only be developed upon an adequate base of inventions in communication, aviation, and organizational innovations.[3]

It is possible to go beyond the fact of interrelated change to the description of patterns of culture growth. Thus, we know that interrelated change is accumulative in character. A physical invention or group practice, introduced into the culture, requires additional inventions for its integration or incorporation into the life of the society. For example, there is the case of the automobile necessitating

1825 — The Erie Canal

Public Roads Administration

The illustrations in this article present examples of technological changes in the field of

safety and traffic legislation, improved roads, safety education, insurance services, and giving rise to the establishment of new governmental agencies. Again, interrelated change is elaborative in character. A new invention must be improved; it must be made more dependable, flexible, sensitive to control; it is called on to perform additional tasks; it may be thrust into novel situations requiring new technics and technical skills. Aviation is a first-rate example. Still again, interrelated change is accelerative in character. As the stock of existing technology and technics enlarges, the rate of discovery and invention increases – at least for a period. The pattern of increase is like that of the compound interest curve but of course cannot increase indefinitely. Like all phenomena of growth, the beginning is slow; there is then a period of rapid growth and development, and a deceleration as saturation is reached, or as one form of growth is replaced or supplanted by another. Even in the period of most rapid growth, however, the rate of change is not uniform or constant but irregular, for growth in one area of social life is more rapid than in other areas. Several factors create nonuniformity and strains in culture change: differential rate of borrowing, the blocking of the development of one area of society by the vested interests of another, fear of the new, or legislation for "redistributing" a nation's wealth. Finally, interrelated change is integrative in character. The elaboration of a given culture complex – for example, transportation – calls for devices which will fit it into the total pattern of the culture. This work of integration in a machine society can never be complete. It may, indeed, be a perennial source of dissatisfaction. Yet it is likewise the perennial necessity which mothers invention. An inventive civilization survives by its inventive wit.

Problems for Social Policy

A changing culture needs some way of anticipating the rate and the pattern of change to which it is subject. This need is dictated by the principles of growth outlined in the preceding paragraphs.

Unhappily, as S. Colum Gilfillan[4] has shown, the record of successes in the field of prediction is slight and not reassuring. For dependable generalizations, we still look forward to an intensified scholarly research in the future. At present, however, the predictability of social change is based upon the following experiences. First, trend lines can be established and the extrapolation of observed trends provides some basis for assessing the probability of certain future events. In any area of technological or social change, determination of trends is facilitated by observations in related fields, for any single invention is, after all, "a multitudinous collection of little ones."[5] Second, embryonic inventions have a slow growth; they grow rapidly in their adolescent stage, and when maturity is reached the rate of advance is once more diminished. Third, inventions have causes, and cause and effect relationships can be formulated. Such invariant relationships have predictive value when properly established. Fourth, curiosity, coupled with analytical summaries of failures and successes of previous predictions, provides certain checks and balances which should establish reasonable criteria for the judgment and evaluation of predictive formulas. Finally, time will often elapse before the full effects of an innovation have matured. This period provides an excellent opportunity to study and forecast other inventions which the present one requires or will make necessary. In general, then, sound social policy can and should make some attempt to gauge the pattern and rate of change.

The problem of anticipated change is aggravated not merely by the lack of scholarly studies, but even more by the presence of certain harmful social attitudes. Sentimental optimism, wishful thinking, the popular resistances offered by tastes, customs, and laws, preoccupation with material profit, and a total unconcern with social consequences – all these factors have delayed systematic efforts to answer the questions of anticipated inventions and their usually unanticipated consequences. This fact means, then, that social policy must reckon with the many ways in which individuals and groups, even the total culture, inhibit the process of change.

1869 — The Meeting of the Rails

Public Roads Administration

transportation which in retrospect have startlingly affected our way of life.

Public Roads Administration

1900 — The Horseless Carriage

Paradoxically, the resistances often spring from a social philosophy about change itself. In a comprehensive catalogue Hornell N. Hart, sociologist, has outlined these failures and blockages in social attitudes as follows:[6]

A. Self-satisfied attitudes:

1. Fatalistic optimism: "Progress is inevitable; all we need to do is to accept and use it."
2. Aggressive culture conceit: "Progress has been and will be the peculiar achievement of our people, or race, or nation; we should spread our culture over the rest of the world."
3. Conservative exploitation of past progress: "We have arrived; the progress of the past has brought us to the present ideal state of affairs, which may now be used and enjoyed."
4. Proud opposition to changes from past achievement: "Let well enough alone; whoever attempts to modify the wonderful institutions devised by our forefathers should be repressed or punished."
5. Changelessness: "What has been good enough for all my ancestors is good enough for me; let it remain as it always has been."

B. Pessimistic attitudes:

1. Sentimental pessimism: "The good old days are never to return; let us mourn them."
2. Fatalistic despair: "Inevitable disaster impends; get what you can out of life before the crash comes."
3. Cyclicalism: "Civilizations rise and fall in waves or cycles. At present we are past the crest of a culture wave and are on the decline into a new dark age. All we can do is to recognize this fact and adjust ourselves to it."

C. Reconstructive attitudes:

1. Repristination: "Let us go back to the old days and restore the glory that is departed."
2. Panacean alarmism: "Unless we act quickly civilization will perish; come and help put into operation the one essential remedy."
3. Meliorism: "Progress is the fundamental trend, but it is subject to reverses (which) may be mitigated and even eliminated. . . ."

D. Agnostic attitudes:

1. Anthropological positivism: "Progress and regress are subjective, and therefore unscientific terms."

It is possible that this catalogue of resistances is simply an armchair listing of hypothetical cases. However, a careful study of several historic social innovations by Theodore K. Noss suggests a contrary view.[7] Noss investigated the opposition to seven social changes, all eventually accepted by the American people: parcel post, postal savings, rural free delivery, bobbed hair, woman suffrage, simplified spelling, and hookworm treatment. He concluded: "As the change cannot be adopted until society agrees to accept it, enough time intervenes between the introduction and social acceptance for organized resistance to appear. The first to oppose the innovation are those who conceive of it as interfering with their interests in society. Under this threat special interest groups become more self-conscious. The members of the group turn to each other for consultation and support. This interaction serves to consolidate the group internally and partially to isolate it from the larger society, but at the same time the members imaginatively identify themselves with society, especially with the social good. Typically, they exaggerate the importance of their group functon and may call themselves the cornerstone of the social welfare. . . . They may predict that social destruction will be the end result of the adoption of the innovation. As a result of their interaction, they develop what they call the 'truth' of the situation. . . ."

In a similar review of the resistance to technological innovations in several fields – transportation,

(*Continued on page 169*)

Twentieth-Century Highway Masterpiece

Public Roads Administration

THE INSTITUTE GAZETTE

PREPARED IN COLLABORATION WITH THE TECHNOLOGY NEWS SERVICE

School of Industrial Management for M.I.T.

Alfred Sloan Foundation Gives $5,250,000 to Purchase Building and Underwrite Its Educational Program for 10-year Period

A GIFT of $5,250,000 from the Alfred P. Sloan Foundation, Inc., for the establishment of a School of Industrial Management at the Institute was announced by Karl T. Compton, chairman of the M.I.T. Corporation on December 20. When put into operation, the new School of Industrial Management will increase to five the schools of instruction at the Institute: in addition to the Schools of Science, Engineering, and Architecture and Planning, a School of Humanities and Social Studies has been announced.

The concept of the new school will be to correlate the complex problems of management in modern technical industry with science, engineering, and research. The objective will be to prepare young men of today better to meet the exacting demands of industrial management. In making the announcement, Dr. Compton said:

Plans for the new school have been under consideration for some time. They are announced now because desirable facilities are available. Both the Institute and the Sloan Foundation realize that the present threats to our peaceful way of life may interpose delays and complications in the development of this new program. However, the urgent need for the highest standards of management which can be developed in the industrial field is ever with us, whether our nation is in a state of emergency or in a state of peaceful prosperity. In fact, industrial management has been termed America's most powerful "secret weapon."

Consequently, the plans for the new school will go forward as rapidly and effectively as conditions permit in order that its contribution, in either war or peace, may be realized as rapidly as possible. Approximately $2,500,000 of Mr. Sloan's gift will be used to provide the essential facilities, including housing and other capital costs. The balance, at the rate of $275,000 a year for 10 years, will serve to underwrite its educational program and administration.

In confirming the gift of the Alfred P. Sloan Foundation, Inc. in establishing the new School of Industrial Management, Alfred P. Sloan, Jr.,'95, said:

It has been my observation over an experience of many years in technical industry that executives with a background of science and engineering are unusually well qualified to deal with the intricate problems of industrial management in our technical enterprises. And American enterprise is passing more and more into that area. That really is the basis of my concept in establishing this School.

Few realize the broad and exacting demands made upon the industrial executive of today, especially in large-scale enterprises. While the exercise of sound business judgment will always be the keystone of a successful industrial executive and a progressive enterprise, yet to reach the highest level of effectiveness, executive decisions must be supported by a scientific appraisal of all related facts and circumstances. Industrial management has passed through a long process of development as our industrial age has evolved. Today it has become in every sense of the word, a matter of science. Therefore, it seems entirely logical that a scientific background offers an unusually healthy climate for the development of tomorrow's industrial executive.

Our present national situation dramatizes a recognized fact; namely, that production is both a source of economic progress and the foundation of national security. It is equally true that management is the motivating force that determines the effectiveness of production.

In the administration of the school, it is my hope that emphasis will at all times be laid in bringing into the training, in a truly realistic manner, the practical problems that face the industrial executive in his administrative capacity. The contribution that the school can make in the future to higher standards of economic leadership will, as I see it, determine the extent to which that is accomplished.

Dr. Compton revealed that the new school would be housed in a separate building, and that Lever House, formerly the headquarters of the Lever Brothers Company in Cambridge, had been purchased for that purpose. The building, which is well adapted for the purposes of the school, stands on a large plot of land adjoining the Institute's grounds.

Use of the existing structure will avoid dependence on new building construction at this time, when materials and labor should not be unnecessarily diverted from the requirements of the national emergency. If this country should be plunged into all-out war, the newly acquired building can be temporarily utilized for emergency projects.

In accepting Mr. Sloan's offer to establish the school, Dr. Compton and James R. Killian, Jr., '26, President of M.I.T., said in a joint statement:

This magnificent gift of Mr. Sloan, whose gifts to M.I.T. now aggregate $7,000,000, makes it possible for the first time to fully capitalize the Institute's resources in a program which will contribute most effectively to the broader status and higher scientific level of industrial management. The record of the Institute's graduates, of which Mr. Sloan is an outstanding example, bears out our convictions as to the effectiveness of a scientific background as a foundation upon which to build a broad concept of management.

Our technological age is based upon the concept of fundamental knowledge gained through scientific research together with the technique of applying this knowledge through managerial skill and inventiveness. These technological developments have resulted in our great industries whose productivity and resulting service to the public depend upon intelligent administration. We believe that such administration must increasingly represent a union of scientific knowledge and its application for managerial ends. Our program will be based on the conviction that industrial management is a profession which can be developed and taught.

Humanities – the Fourth School

REPLACING the Division of Humanities, there has been established a School of Humanities and Social Studies at the Institute, giving formal recognition to programs long emphasized at M.I.T. in general education and in social science. In making this announcement in December, James R. Killian, Jr.,'26, President of M.I.T., said:

> M.I.T.'s fourth school will have the responsibility for providing the strongest possible program in general education for students studying in the fields of science, engineering, and architecture. In addition, the new school will be a center for creative and professional work in such social sciences as economics, which are appropriate to an institute of technology.

Dr. Killian also announced the appointment of Professor John E. Burchard, '23, as dean of the new school, which will have equal status with the Schools of Science, Engineering, and Architecture and Planning. Dean Burchard, since 1948, has been dean of the Division of Humanities, which is now replaced by the School of Humanities and Social Studies.

The creation of the new School of Humanities and Social Studies does not mean that M.I.T. plans to develop a school or college of liberal arts or to give degrees in the liberal arts. Dr. Killian emphasized that:

> We shall remain an institution of limited objectives, offering as we have for many years a program centered around science, engineering, architecture, and management. The new school is designed to enable the Institute to broaden and deepen its activities in these fields and to educate men who can be effective citizens as well as effective professional practitioners.
>
> Our purpose is to give men professional competence and at the same time an insight into the society in which they live and to which, as scientists and engineers, they will have great responsibilities.

The new School of Humanities and Social Studies and new sequences in humanities for the professional programs of M.I.T.'s other schools were both recommended by an M.I.T. Faculty Committee on Educational Survey in its report made public in September, 1950.

The M.I.T. Faculty has approved plans for the integrated program of humanities in professional technical curricula, to include: (1) A two-year sequence of courses in humanities and social science, to be a required part of the freshman and sophomore years of all professional courses at M.I.T.; (2) Four additional courses in these fields during the junior and senior years of all professional courses, with provision for six such courses for students who wish to devote more time during those years to the humanities and social sciences.

The recommendations of the committee, subsequently approved by the entire M.I.T. Faculty and the members of the M.I.T. Corporation, direct the new school to "consider the advancement of knowledge an essential part" of its program, to assume "the responsibility for planning and administering the program of general education as a part of the common curriculum in science and engineering at M.I.T., and to offer professional courses leading to graduate as well as undergraduate degrees."

The new School of Humanities and Social Studies at M.I.T. will be guided in its development by the recommendations of the Committee on Educational Survey. In its report, the committee proposed a unit to serve the Institute "by planning and administering a general educational program for all M.I.T. students, designed to develop an awareness of the interrelations of the scientific, technical, and literary cultures, and a sensitiveness to the diverse forces that motivate the thoughts and actions of people. This general educational program, like all components of M.I.T. education, will grow out of the creative work of the departments, and it must be an integral part of the professional curricula, far more than a mechanical mixture of the conventional literary and technical cultures."

Ground Broken for Laboratory in Food Technology and Biology

On November 15, members of the family of the late John Thompson Dorrance, '95, and ranking officers of the Campbell Soup Company (of which Mr. Dorrance was president from 1914 to 1930) were guests of honor at outdoor exercises to break ground for the Institute's new John Thompson Dorrance Laboratory. Taking part in the exercises were (left to right): *President Killian; Karl T. Compton, chairman of the M.I.T. Corporation; Oliver G. Willits, Vice-president, Campbell Soup Company; and Mrs. John Thompson Dorrance.*

The new seven-story building, 57 by 200 feet, will provide critically needed facilities for the Institute's Departments of Biology and Food Technology.

M. I. T. Photo

At the Council

With an attendance of 113 members and guests, the 278th meeting of the Alumni Council was called to order by John A. Lunn, '17, President, on November 27, at the conclusion of dinner in the Campus Room at the M.I.T. Graduate House.

As first speaker of the evening, Gerald B. Tallman, Associate Professor of Marketing, outlined the evolution of the Alfred P. Sloan Fellowship Program for training young men in executive development. Although the M.I.T. program is the smallest of the executive training programs now in operation in colleges in the United States, it is the oldest, most selective and comprehensive. More than 1,000 companies are circulated each year for their endorsement of candidates who come to the Institute for a year of graduate study with expenses paid by the Sloan Fellowship Program and the candidate's employer. This year 14 young men have been selected and are now studying at the Institute.

President Lunn then called on Professor John Wulff, of the Department of Metallurgy, who is director of the new Sloan Metal Processing Laboratory now under construction at Vassar Street and Massachusetts Avenue – adjacent to the Guggenheim Aeronautical Laboratory. Professor Wulff described the physical facilities of the new laboratory for instruction and research in all phases of metal operations, and outlined the manner in which the new laboratory would be used on a co-operative basis by the Departments of Mechanical Engineering, Metallurgy, and Business and Engineering Administration.

This new program will combine, in a manner not previously attempted in an educational institution, the theoretical and practical aspects of metal processing. Professor Wulff pointed out that each year 800 students take machine tool laboratory and 800 students study methods of metal forming. At the present time, about 40 bachelor's, 15 master's, and 12 doctor's theses are being undertaken in this co-operative program which the metal industries are supporting, especially since a definite need exists to introduce scientific procedures in metal-processing operations which, for generations, have clung to apprenticeship methods. Although industry and professional groups are supporting research and teaching in the new laboratory, Professor Wulff emphasized that the new laboratory would be used primarily for undergraduate instruction. Nevertheless, the close contact between the Institute and industry is expected to have many mutual advantages in this program.

During the business portion of the meeting which preceded these two addresses, Donald P. Severance, '38, Secretary, reported that between September 27 and November 20, 1950, eight M.I.T. clubs had been visited by seven different members of the Faculty and Alumni Council. A gavel was presented to C. Adrian Sawyer, Jr.,'02, in appreciation of his splendid term of office as president of the Alumni Association for 1949–1950. It was also announced that George Warren Smith,'26, had been named chairman for the Association's Midwinter Meeting of Alumni in Greater Boston, which is scheduled to be held in Cambridge on February 1, 1951.

Administrative Aide

The appointment of Professor Gordon S. Brown, '31, as Associate Head of the Department of Electrical Engineering was announced in November by Professor Thomas K. Sherwood, '24, Dean of Engineering. Professor Brown, who is director of the Servomechanisms Laboratory, will share administrative responsibilities for the Department with Professor Harold L. Hazen, '24, who has been its head since 1938.

The Department of Electrical Engineering, the largest in the Institute, has a registration of 902 students, of whom 302 are studying in the Graduate School. In addition to its undergraduate and graduate educational program, the Department carries on research which, on the basis of budget, is as comprehensive as the operations of industries with comparable personnel. Thus, the administrative responsibilities of this single Department are comparable to those of many small colleges. Its academic staff, including the junior grades of assistant and research assistant, totals 260 members, while the entire personnel numbers 750. During the postwar peak, student enrollment in the Department of Electrical Engineering exceeded 1,200. Associated with Professors Hazen and Brown is Professor Carleton E. Tucker, '18, Executive Officer.

Dr. Brown, a native of Australia, was educated at the Institute, received the degree of bachelor of science in 1931, the master's degree in 1934, and his doctorate in 1938. He joined the Institute's staff as a research assistant in 1931, was appointed assistant professor in 1939, associate professor in 1941, and became professor of electrical engineering in 1946.

Professor Brown is internationally known for his contributions in the field of servomechanisms. At the opening of World War II, M.I.T. had the only university servomechanisms laboratory in the country, and Dr. Brown and his colleagues at once undertook a program of research for the armed services that contributed notably to successful operations against the enemy. Since the end of the war, the laboratory has been engaged in research of important industrial significance.

Employees Receive 25-Year Pins

A group of Institute employees who collectively have served M.I.T. for a total of 2,020 years received service pins this fall, honoring their long service, at the first presentation ceremony of its kind in the Institute's history. Sixty-six men and women were thus honored with gold pins indicating 25 or more years of service. But exceeding all others in years of association with M.I.T. is Julia M. Comstock, long in charge of the Institute's historical records, who has served M.I.T. for 58 years. Miss Comstock came to the Institute in 1892, when General Francis Amasa Walker was president, and only 30 years after the Institute's founding in Boston. She has served during the administration of 10 presidents of M.I.T.

The pins were presented at exercises in which President Killian and Dr. Compton spoke and congratulated the veterans on their long service. High light of the ceremony was the presentation of Miss Comstock's pin by Professor Emeritus Samuel C. Prescott, '94, for-

M. I. T. Photo

To Julia M. Comstock are M.I.T. Faculty and staff appreciative for maintaining an accurate record of their associations with the Institute. Her years of service exceeding the 25 years depicted on the pin shown in the upper left corner, Miss Comstock is well versed in M.I.T.'s history.

mer Dean of the School of Science and Head of the Department of Biology and Public Health for many years. Next in years of service were Carl G. Selig and Edgar L. Pung, with 45 and 42 years respectively.

The 41 men and 25 women receiving the pins were: *Admissions Office:* Anne L. Riley; *Alumni Association:* Madeline R. McCormick; *Buildings and Power:* James S. Alexander, Robert Baillie, Walter G. Baker, James B. Broderick, Herbert M. Candow, Raymond S. Howell, Robert K. Jenner, Alexander H. Johnson, Norman Lander, Patrick B. Manning, Ralph Metzger, Philip Monticelli, Alfred W. Moore, John M. Moran, William P. O'Connor, Edmund J. Petacchi, Ernest L. Roberts, Abner Stodder, Theophilus Tucker, Berthold U. Uriot, Charles J. Webber; *Department of Business and Engineering Administration:* Olive Barnard; *Chemical Engineering Department:* Harold H. Carter; *Chemistry Department:* Norman B. Carter, Mrs. Marion S. Cunningham, Edward J. Curtis, Charles L. Gallagher, Edith M. Nelson; *Civil Engineering Department:* George W. Broussard, Ernest O. Dennison; *Dormitories:* Thomas H. Chambers, Sidney W. Elder, Wilfred P. Samuels, Archibald H. Sutherland; *Division of Laboratory Supplies:* Mrs. Edward Driscoll, Arthur B. White; *Dean of Students' Office:* Verna L. Keith; *Electrical Engineering Department:* Ednah Blanchard, Frederick E. Broderick, Henry J. Laurence; *Historical Records:* Julia M. Comstock; *Letter Shop:* Doris E. Peabody; *Library:* Gertrude Perry, Louise Trainor; *Mechanical Engineering:* Harry C. Artis, Herbert A. Johnson; *Medical Department:* Alice M. Browne, Mrs. Harold A. King; *President's Office:* Mrs. David W. Edwardson; *Physics Department:* Carl G. Selig; *Registrar's Office:* Marjorie J. Doherty, V. Louise Holmer, Mary C. Hurley, Mrs. Joseph C. MacKinnon; *Superintendent's Office:* Louise S. Buttrick, Elizabeth A. Young; *Walker Memorial:* Eugene Blacquier, Maude P. Lunney, Mrs. Mary E. Lynch, Mrs. Carlton MacLean, Edgar L. Pung, Irene Sullivan, Alexander J. Sylvestruck, Max J. Wall.

Piloting the Course

THE Visiting Committee on the Department of Aeronautical Engineering* held a meeting on March 21, 1950, to inspect the Department's facilities and discuss its activities with the Faculty. The morning and part of the afternoon were largely devoted to inspection of the facilities, which included the new Naval Supersonic Wind Tunnel, graduate and undergraduate laboratories, and classroom accommodations. After the inspection, a conference was held and the Committee was informed of the activities and problems of the Department. The conference adjourned late in the afternoon to be resumed informally at a dinner at the Union Club.

From informal discussions conducted during the year, it was possible to poll the opinions of the members of the Committee on certain subjects, the results of which are expressed by the following points of agreement:

1. The Department of Aeronautical Engineering is doing an extremely effective job and is staffed by competent and active men.

2. The facilities of the Department are effectively operated and well cared for.

3. An alteration to the Wright Brothers Wind Tunnel, to provide for a new transonic intermittent chamber, is desirable.

4. The aeronautical courses now in force, which include a co-operative course, a course directed toward a degree of aeronautical engineer, and the honors course are excellent additions to the Department's curriculum.

The Committee feels that, whereas graduates from this Course have been successful in the past and there is every reason to believe that the success will continue, every effort should be made to follow the graduates' careers so that the results of experimentation and changes in student curriculum can be evaluated. The Committee believes that a major technical study should be made to cover the activities of the rank and file who may not be singled out by publicity. Such a general study would not only be useful to the Institute as a whole, but permit comparison between the results of courses in the various departments of the Institute. It is realized that this is a big undertaking and that some compromises will have to be made. It is suggested that the statistics cover a period of the past 25 years, and that they be reviewed and added to at some regular interval — perhaps at five-year periods.

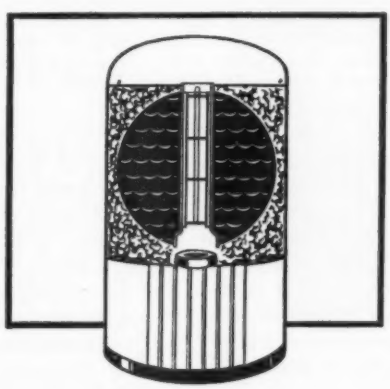
Discussions ensued concerning the reason for the decrease in enrollment of students in aeronautical courses, and questions were raised as to whether such a decrease was general and applied to other aeronautical engineering schools as well. This problem, which has been a matter of concern to the Department for some time, was discussed with the chairman of the Committee who, in turn, circularized and obtained information on student enrollment from 18 engineering schools. The result of such investigation indicates

* Members of this Committee for 1949–1950 were: Luis de Florez, '11, chairman, Godfrey L. Cabot, '81, Theodore P. Wright, '18, James H. Doolittle, '24, George J. Leness, '26, Preston R. Bassett, and Leroy R. Grumman.

BUSINESS IN MOTION

To our Colleagues in American Business . . .

The geometric form that combines the maximum volume with the minimum surface is the sphere. This fact has been obvious to man for centuries, but it was only a relatively few years ago that this principle was applied to a domestic water heater. It was reasoned that if a heater had a spherical tank, it would lose less heat by radiation than the conventional cylindrical tank. The theory was absolutely correct, but as is so often the case, making it practical was not easy. A sphere can of course be built up of segments, but that is a costly process, and in order to make a heater that would be competitive, as well as have maximum heating efficiency, it was desired to make the sphere in two halves and weld them together, with a central tube for the flue, which would heat the water from the center out instead of from the outside in.



In order to obtain easy weldability, plus the corrosion resistance of copper and the strength of mild steel, Herculoy was chosen. This is Revere's silicon bronze. Welded tanks made of it are non-rusting, long-lived, and easily meet code requirements for a 300-pound pressure test. The manufacturer who undertook production of this tank was exceptionally well staffed with metallurgical, design and fabrication engineers, so much so that it would have been logical to believe they could solve all the inevitable problems without assistance. Nevertheless, they asked Revere to collaborate with them, probably feeling, we believe correctly, that Revere's knowledge and experience added to their own would materially shorten and facilitate the work required to set up successful production methods.

One subject of examination was the drawing of flat sheets into hemispheres, which requires correct drawing sequences and anneals. Studies were made of the furnaces in the customer's plant, and the correct temperatures and annealing times were worked out together, so that the proper tempers were produced. Then the welding process was studied mutually with Revere's Welding Department. Methods, current densities, welding times and other factors involved in establishing a proper welding sequence were specified. Later, new welding techniques, such as the hydrogen-shielded arc, were incorporated.

The domestic water heater that resulted from this exceptionally thorough engineering job is extremely efficient in its use of fuel, and in its conservation of heat through reduction of radiation. It is reported that stand-by losses are so low that they are made up by the small amount of heat from the pilot, when no water is being drawn off. That is operating economy, while savings are also afforded by the non-rusting silicon bronze tank, an especially important factor where water conditions are such as to destroy ordinary metal quickly.

This case history of close collaboration is especially pleasing to Revere, because of the high degree of engineering talent employed by the customer. It paid even him to look outside as well as within for knowledge and experience. So we suggest that whatever it is you make it will pay you to ask your suppliers to add their knowledge to your own. They will be glad to do so, and the result may be pleasing and profitable indeed.

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The warmth and cordiality of this group from South America were evidenced last July when the M.I.T. Club of Venezuela in Caracas was organized, bringing the total of M.I.T. clubs to 86. Representing the youngest of the clubs with exuberance which resulted in definite plans to establish and maintain close association and co-operation with the Institute were (left to right): *Gerald A. O'Connor, '29, Vice-president; Victor M. Lopez, '36; Melchor Centeno, '30; Felipe Echaniz, '43, Secretary; Walter V. Skees, '33; Oscar A. Machado, Jr., '43; Whitney Ashbridge, '26; Luis G. Jimenez-Michelena, '41; Enrique J. de Majo, 6–45; John W. Matthews, 10–44; Gabriel M. Disario, '28; Guillermo Machado-Mendoza, 2–46, President; Christa Kern, who acted as recorder; Diego C. Carbonell, 6–45; Armando Medina, '47; Juan A. Vegas, 6–45; Alfredo Rodriguez Delfino, 10–44; Dr. Curiel, (Harvard), President, National Institute of Sanitary Works; Hugo Perez La Salvia, 6–45; Rafael de Leon (Harvard); Ricardo Zuloaga, '42; Francisco Acevedo-Quintana, 6–46; Atahualpa Dominquez, 2–46; Dr. Sanabria (Harvard), Dean, Technological College; Ely Mencher, '38; Guillermo Zuloaga, '30; James E. Dorris, '38; Carlos L. Bethencourt, '48; David D. Brillembourg, '47; Nestor E. Perez, 2–46.*

that the lessening of aeronautical students is general and that it is the result of a number of factors, among which are: (a) a shift of interest of the students since the close of World War II to other fields, such as electronics and physics; (b) reductions in government appropriations for aeronautics; and (c) a feeling on the part of the students and parents that an aeronautical engineering course is too highly specialized and offers less opportunity for possible employment in other fields.

It was the opinion of the Committee that a properly trained aeronautical engineer, who graduates from the Department of Aeronautical Engineering, should not be considered more highly specialized than any other graduate of the Institute in respect to being competent to undertake jobs outside of his field. The Committee feels that some study and effort should be directed toward the counteracting of this misapprehension.

5. The development of aeronautics to the present date has been almost entirely directed toward development of air frames, engines, and flight accessories, with the result that at the present time the extraordinary progress made in aircraft appears to be far ahead of the ground facilities required for their operation. Such a one-sided development is understandable if it is realized that development of flight equipment has received tremendous financial support and has attracted the most talented, enthusiastic, and highly trained men. It is felt by the Committee that, in addition to training of aeronautical engineers, the Institute might well take notice of the vast opportunities for technical graduates in solving the tremendous problems which arise from the operation of aircraft itself, and that perhaps courses or options could be devised which would interest students and graduates in seeking careers in this important phase of aviation known as "ground aviation."

6. The matter of original design exercises, as a part of the undergraduate curriculum, was discussed. The Committee feels that the Department has good reason to continue the policy of having students make an airplane design from specifications, and that it would be desirable to adopt the procedure current in architectural courses – that of comparing and criticizing designs with a view toward producing competition. It was also the Committee's belief that a small yearly prize for best or most original designs would be valuable in creating interest and stimulating thought. Various companies in the aeronautical field will be contacted by the Committee in an endeavor to obtain such prizes.

7. The Committee feels that the work and future of the Department of Aeronautical Engineering is in good hands, and it wishes to express its appreciation of the quality of the work being done and the keen interest shown.

Books Aid Bangkok University

A GIFT of $100 worth of new American medical books, sent by students of M.I.T. through the CARE-UNESCO (United Nations Educational, Scientific and Cultural Organization) Book Fund, has brought needed help to a Far East university whose book supplies are so low that students and professors must use mimeographed copies of the few precious texts they have on hand.

Positive Heat shut-off at Each Radiator

The $10 million Park View development in Collingswood, N. J., is the largest post-war apartment in the Philadelphia area. The arresting design with an almost unbroken expanse of window space has won professional acclaim. Television, radio and newspaper promotions have brought thousands to the model apartment.

The owners of Park View put comfort first. They provided a "Controlled-by-the-Weather" Webster Moderator System of Steam Heating. With fully recessed Webster System Radiation . . . Convector Radiators with built-in radiator trap and valve. Each radiator has a convenient, accessible, easy to operate handle providing complete shut-off at tenants' convenience.

With the Webster Moderator System, heat is delivered continuously – plenty of heat in really cold weather, mild heat for mild days. The supply of steam is varied automatically with changes in the weather. There's a Webster Radiator Valve for 100% heat shut-off from each radiator – no dampers are needed.

Park View is owned by Sylvester A. and Sylvester J. Lowery. The Builders are S. J. Lowery and E. J. Frankel. The architects were J. Raymond Knopf and Samuel J. Oshiver (associate). Engineers included Robert E. McLoughlin, Salvatore S. Guzzardi, and Robertson & Johnson. The heating contractor was Benjamin Lessner Co., Inc.

Park View interior showing Webster System Radiator. Flush-with-wall, takes no useable room space. Metal front provides easy access if necessary. Convenient, quick shut-off handle.

Park View was financed through County Trust Co., Tarrytown, N. Y., with the Seaman's Bank for Savings of New York as permanent mortgagee. It is insured by FHA.

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TRYLON TOWERS and MASTS

THE BLASTED BORE

(*Continued from page 146*)

cept such a dangerous substance for transport at the time of the construction of the Hoosac Tunnel.

A disastrous fire in the wooden structure at the central shaft occurred during this period when a tank, used to store naphtha for experimental lighting, exploded. The central shaft's pumps were shut down by the fire and 13 men drowned, and work in the shaft was abandoned for several months. There were many charges of graft during the state direction of the work, and it was finally decided that the tunnel project could be better handled under contract, providing a contractor of the requisite financial resources and construction ability could be found who would be willing to accept the job.

Period of Success (1869–1876)

Yankee pride must have suffered considerably when it became evident that not a New England, but a Canadian; firm should be given the contract to finish the tunnel: the firm of Walter and Francis Shanly. Born in the County of Queens, Ireland, Walter Shanly had emigrated to Canada where he had engaged in various pioneer construction enterprises, becoming general manager of the Grand Trunk Railroad. Among his other activities, he was a representative in the Canadian House of Commons. The Shanly contract was dated December 24, 1868, within a few months of the date of the patent by George Westinghouse for the railroad air brake; and the pioneer development in the use of compressed air for blasting and the railroad air brake thus continued during the same period. The nationwide celebration on the completion of the Pacific Railroads would occur in May of the next year (1869). Work on the one-half completed central shaft (a 15 foot by 27 foot ellipse in cross section) was resumed in the same month, and it was excavated to tunnel grade in about a year, making it possible to work the tunnel from four headings. Hindsight tells us that this shaft should have been started earlier; less than 15 per cent of the tunnel was excavated from the two headings leading from it.

The mixture of glycerin with nitric and sulphuric acids, which is nitroglycerin, was made in liquid form in a plant located near the west portal of the tunnel. A dramatic incident was to teach the Hoosac Tunnel folks of the greater safety of nitroglycerin in solid form. Until then, they had carefully followed the current literature, which warned against its supposedly more dangerous solid state, and the workmen during that era were not taking chances on any unproven methods for handling this volatile material.

Nitroglycerin Experiments

Ten cartridges of nitroglycerin had been carefully packed under a buffalo robe in the sleigh of William P. Granger, chief engineer, in the phenomenally bitter winter of 1867–1868, a year before the start of the Shanly contract. He was to take them across the moun-

(*Continued on page 162*)

What GENERAL ELECTRIC People Are Saying

T. M. BERRY

General Engineering & Consulting Laboratory

CONTOUR FOLLOWER: The optical contour-follower control is an automatic curve-following device. It has several unique features which make it ideally suited for use as a machine-tool control for the purpose of reproducing, in metal, a shape designated on a line drawing.

A number of machine-tool controls of the template-follower type are in general use for machining duplicates from a metal master pattern. The optical contour follower is used in making the master pattern itself.

In many cases thousands of duplicates are made from a single metal master, and only a few masters are required. The amount of time and labor involved in making these few accurate masters is relatively unimportant. Developmental manufacturing, however, requires that a master be duplicated only a relatively few times and that a much larger number of masters be made. In this case the time and labor involved in making a master are very important. It was for the purpose of reducing this time and labor that the optical contour follower was developed . . .

"G.E. Review"
June, 1950.

★

J. P. DITCHMAN

Lamp Department

PLANT LIGHT: The advent of new artificial light sources stimulates the efforts of plant physiologists and other scientists to solve the fundamental riddle of how plants grow. Carbon arc incandescent lamps, sodium lamps, mercury lamps, and many combinations of these have been used in growth chambers where light, humidity, temperature, and air are controlled to grow plants entirely under artificial conditions. Today laboratories are being equipped with combinations of fluorescent and incandescent lamps for this purpose. . .

There are many laboratories in agricultural colleges equipped with rooms for growing plants entirely under artificial conditions, trying to develop methods independent of natural conditions. These research objectives, it is said, could lead (if successful) to political and economic consequences which could rival those of the atomic bomb. If we could maintain food production under ground, we could provide a hedge against some of the spectacular devastation feared in an atomic war.

Illuminating Engineering Society
Pasadena, California
August 21, 1950

★

H. A. LIEBHAFSKY
A. E. NEWKIRK

Research Laboratory

CORROSION STUDIES: The annual cost of corrosion is so great that it is desirable to explore every promising technique for the investigation of corrosion processes. Among the most feared of these processes is pitting, which, being a form of localized attack, is well suited to investigation by methods such as radiography that depend upon the absorption of x rays.

To illustrate the value of these methods, the pitting of three kinds of stainless steel in ferric chloride solution at room temperature has been studied. Radiographs have been obtained that show how pitting varies with the kind of steel and with the degree of cold deformation. Furthermore, it has been possible to demonstrate that the direction of attack can be profoundly influenced by gravitational forces and by the occurrence of crevices. While the radiographs largely confirm past experience, they provide much detailed evidence that might escape visual observation . . .

Finally, it has been possible to measure the rate of pit growth on specimens continuously immersed—an important fact, because removal of the specimen from ferric chloride solution can stop altogether the growth of particular pits. The technique employed could be used to measure in favorable cases the rate of pitting in closed systems.

National Academy of Sciences
Schenectady, New York
October 10, 1950

★

J. P. RUTHERFOORD

Apparatus Department

STREET LIGHTING: Kansas City, working with the Kansas City Power & Light Company, has almost completed a postwar relighting program. By using modern, efficient, highly effective equipment, the total number of luminaires on Kansas City streets has been reduced from approximately 15,000 under the old system to about 13,500 under the new system.

The total effective lumens, however, have been increased from approximately 11,500,000 under the old system to approximately 49,000,000 under the new system. In spite of this tremendous increase in effective lumens on the street, the annual street lighting bill to the city has increased from $552,000 per year to only $626,000 per year.

If you evaluate that in terms of lumens on the street, the people of Kansas City were paying approximately $47.53 per 1000 lumens under the old system and are presently paying only $12.80 per 1000 effective lumens under the new system.

Rotary Club
Weymouth, Mass.
July 24, 1950

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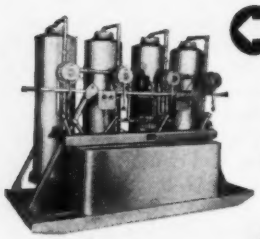

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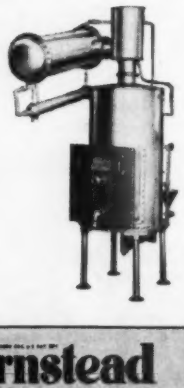

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THE BLASTED BORE

(*Continued from page 160*)

tain to blast away an ice jam at the Deerfield Dam. The cartridges had been carefully warmed to 90 degrees F., then filled with nitroglycerin and packed in hot sawdust to keep the nitroglycerin liquid. When the sleigh upset on the icy road, Granger dived into a snow bank and waited for an explosion that did not occur. He picked up the cartridges, now frozen solid, placed them between his feet, and drove to the dam. There, he attached fuse and exploder, inserted the cartridges in the ice, and set off the fuse. Although the exploder drove its copper cap into the cartridge, the nitroglycerin itself did not explode. Later, when thawed out, it was exploded and the ice jam was cleared. This experience taught Mowbray never to transport nitroglycerin except in the frozen state. At about the same time, Alfred Nobel had learned to provide an absorptive dope for the nitroglycerin: a diatomaceous "rotten earth," called kieselguhr. To this solid combination, Nobel gave the name "dynamite."

The nitroglycerin structures were erected in a board-fenced area of about 10 acres. They all appear to have been of timber construction: heating was by stoves until superseded by steam heating, then a novel method, and the structures were lighted by oil lamps. In the Acid House, 150 feet long, the mixture of the two acids was prepared. In the well-lighted, 100-foot-long converting room, 116 stone pitchers sat in nine wooden troughs, filled with ice water. From glass jars, on a shelf above, the pure glycerin was siphoned, drop by drop, into the acid mixture in the pitchers, agitated by air from a blower. The fumes had to be closely watched. If they stopped unduly soon, because of a blower-engine stoppage, the mixture would surely take fire. The normal stopping of the fumes showed when the mixture was complete: The nitroglycerin was then dumped into a large tank at 70 degrees F., in which it settled under six feet of water. Passed into a churnlike wooden tank, the nitroglycerin was washed five times, a current of air stirring it. The water discharge ran via a wood trough through three barrels which caught the residue of nitroglycerin — the water finally discharging into a pile of rocks. When the nitroglycerin was thoroughly washed, a man (a brave man) with a shoulder-borne yoke carried it in two copper pails to the magazine, 300 feet distant. Twenty earthenware crocks contained the nitroglycerin in the magazine: They were placed in two feet of water in a wooden tank, kept at 70 degrees F. by a small steam pipe from the boiler. After 72 hours in the tank, the floating impurities were skimmed off, and the now chemically pure nitroglycerin was ready for packing. It was packed in tin cans, lined with paraffin, of 56-pounds capacity each. The wooden trough in which the tins were placed contained ice and salt to congeal the nitroglycerin. In this condition it remained, ready for use, in the magazine.

The nitroglycerin was transported in wagons or sleighs, across the rough mountain roads in wooden boxes, cushioned by rubber tubes and sponge. Within the tin container, a one-and-one-half inch tube gave space for the later introduction of water at 70 to 90 degrees F., ultimately to thaw out the frozen nitroglyc-

erin for the blaster. Closed by a bladder-wrapped cork, the tins of nitroglycerin were transported to the place of use — in the summer covered by a layer of ice. Incidental equipment comprised two ice plants of 400-ton capacity; a 15-horsepower boiler; and a 10-horsepower engine to pump water into the washing tanks, to operate the two blowers, and to give power to the gutta-percha factory.

So greatly did the tunnel executives distrust the insulated wire of the period that they insulated their own conductors at the site. The details of their methods need not be listed. Briefly, their imported gutta-percha blocks were rasped into pieces, which passed through a trough of water in which the impurities settled, were steamed, masticated and rolled; pressed through gauze and masticated again to make the gutta-percha pure. Gutta-percha, at "95-tons pressure," was forced against the five parallel wires that led through oversized slots, through which the wire to be insulated passed. For some reason, the "lead" wires were given a heavier insulation coating than the "return" wires, perhaps indicating the state of knowledge of electrical engineering in this period.

Great precision was required in the manufacture of the myriad exploders, also made on the site. They were tiny affairs, about one-half inch in diameter, by one and one-half inches in length, to activate which an electric spark would ignite the primer (a mixture of sulphide and phosphide of copper with chlorate of potash) which would set off the fuse (fulminate of mercury in a copper cap) which in turn would detonate the nitroglycerin cartridge into which the exploder was ultimately inserted.

Electricity to set off a blast was supplied by a modified Austrian or frictional plate machine. When in good order this machine would fire 20 to 30 holes, using lead wires 500 feet long. The hazards of misfires caused by the rapid deterioration of the initial machines caused Mowbray to redesign a more rugged type, with a cylindrical exciting surface, enlarged condensing surface, and a ground connection.

Much of the aboveground works at the Hoosac Tunnel are thus seen to have been for the manufacture of nitroglycerin, insulated wire, and detonators, which today would be delivered ready-made to the job.

If danger lurked in the aboveground works of the tunnel, it was a definitely more threatening danger underground. Two miles from daylight, with glimmering candles and flaring lamps, crowded miners worked with steel picks and drills, dodged spoil cars, and, somehow got used to the din of air drills and compressed-air exhausts, all in the wet drip of condensation and leaking seams. Mysterious death lay in wait during the period of learning the rules of safety in the handling of nitroglycerin. Later, death would come to those who were careless in obeying the rules which Mowbray laid down. One must never expose a cartridge to a sudden jar. He should never drill in spots where liquid nitroglycerin had been spilled, but should fire an exploder to clear it up. He should never pour liquid nitroglycerin into a seamy hole, but should use a cartridge. After a blast, he must look for unexploded cartridges. Under no circumstances should he attempt to tamp a drill hole. He should know that

(*Continued on page 164*)

HEVI DUTY

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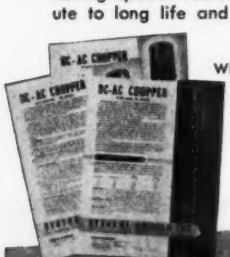

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THE BLASTED BORE

(*Continued from page 163*)

blasts of compressed air could generate static electricity which could cause premature explosions, unless extreme care were taken in wiring the exploders at the cartridges. But the initial prejudice of the Irish and Cornish miners against nitroglycerin ultimately changed to a greater dislike for the noxious fumed gunpowder, and they threatened to strike when it was proposed to deprive them of nitroglycerin for a month, in order to carry on a comparative test with gunpowder. It was the lesser of two evils, and, as good construction men, they rejoiced at the records of progress they were breaking with its use.

The order of work at the west end was as follows: In a period of six hours, 11 holes were first drilled to embrace an area about nine feet wide near the roof. On signal, the cartridges were brought in one vessel — the exploders coming in a separate vessel. The miners were next dismissed, drill holes gauged, and exploders attached to the cartridges which were then immediately pressed into the drill holes. With the holes plugged with a bung and the connections made, the operator retired about 300 feet to a "break" (home-made switch?), where the connections were made to the wires leading to the friction machine, some distance away. After blasting these first holes and after removal of the rock, the drill carriage was advanced and the heading was widened by a second blast of some 14 holes. A third blast of 15 holes completed the heading, advancing it by about seven feet, six inches. At this stage, the heading was nine feet high by the full tunnel width of 24 feet. Simultaneously with the heading work, at about 500 feet to the rear, a gang worked at the bench and, by a third gang farther back, the bench was completed, and the tunnel finished: 24 feet wide by 22 feet high. An adit for drainage was then made in the tunnel floor. Differing from the above-described west end method, the east end was worked by a heading that commenced at roadbed grade, two stopes then being taken from the roof.

With the work progressing from four faces (west end, east end, central shaft toward west, central shaft toward east) eight gangs of 16 men each worked in eight-hour shifts. Other workers made a total payroll of about 900, among the listed employees being platelayers, rock men, cage and locomotive engineers, blasters, dumpers, blacksmiths, machinists, timekeepers, and supervisory talent. The monthly payroll varied from $40,000 to $60,000, to which the item of supplies had to be added.

On Thanksgiving Day, November 27, 1873, success came to the well-planned program of the tunnel engineers and George M. Mowbray, chemist, vigorously carried on by the contracting firm of Walter and Francis Shanly. With the west central shaft heading meeting that from the west portal, there was a clear path through the mountain. In about five years this team had opened 63 per cent of the tunnel. It had taken 17 years to open the other 37 per cent, since the token start of 1851, made in an atmosphere of strong doubt whether the tunnel was at all feasible. Three years later (1876) the various finishing touches, in-

(*Continued on page 166*)

B.I.W.

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PFGGV-600-20	.095"	8.0	#20	7	10	.120"	PFRWX-600-20
PFGGV-600-18	.105"	10	#18	16	15	.125"	PFRWX-600-18
PFGGV-600-16	.120"	15	#16	19	20	.130"	PFRWX-600-16
PFGGV-600-14	.140"	20	#14	19	27	.160"	PFRWX-600-14
PFGGV-600-12	.160"	30	#12	19	37	.225"	PFRWX-600-12
PFGGV-600-10	.190"	45	#10	104	50	.270"	PFRWX-600-10
PFGGV-600-8	.240"	75	# 8	133	67	.350"	PFRWX-600-8
PFGGV-600-6	.290"	110	# 6	133	91	.410"	PFRWX-600-6
PFGGV-600-4	.350"	168	# 4	133	123	.480"	PFRWX-600-4

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THE BLASTED BORE

(Continued from page 164)

cluding the laying of the first track, were finished, and, after one quarter of a century, through service to the West was scheduled, the original reason for starting the tunnel.[10] The Hoosac Tunnel was a going concern.

In a generation that complacently accepted high casualty lists on ventures which required the use of untried materials and dangerous methods, those who built the Hoosac Tunnel wrote their epic of construction courage.[11]

Their job done, those who retained the unbroken limbs needed in their trade moved on to the next construction project. And they probably showed the typical cynicism of construction men when they noted that there were only modest celebrations at the consummation of their stupendous feat of tunnel building. They probably agreed that the completion of the Pacific Railroads was worthy of the nationwide rejoicing that had occurred seven years prior to the finish of the tunnel. But the finishing of this hole in the ground that they had just completed was its own celebration, they would agree. So they would seek some other tract of the rugged bowels of good old mother earth to operate upon.

Those who paid most of the bill of about $14,000,000 for the construction of the tunnel (the Massachusetts taxpayers who have now passed on) would agree that this investment was money well spent, considering its contribution to the prosperity of the region, as the tunnel has served as an important artery of trade with the West for three-quarters of a century. At present, about one third of a million cars bring about 20,000,000 tons of freight from the West every year and carry about 10,000,000 tons back. (Average annual amounts for the years 1940–1949, inclusive.) The sum of these tonnages, 30,000,000 per year, may be compared with the 478,606 tons of merchandise carried by the entire system of the Fitchburg Railroad Company in the year 1854, when the excavation of the tunnel had been barely started. Those who make their living today by the use of rock drills and dynamite will also admit their great debt to the tunnel builders for their pioneer work in the development of these two important agencies in the field of construction and mining. The Hoosac Tunnel has paid off handsomely.

Epilogue

Service through the tunnel began under the Fitchburg Railroad Company which had taken over operation of the Troy and Greenfield Railroad in 1874. In the year 1919, the Fitchburg was merged with the Boston and Maine Railroad which now operates the tunnel. The Hoosac Tunnel soon became known as the worst of American railroad "smoke holes." There is the testimony of the former fireman who would bury his

[10] The second track was opened six years later.

[11] It was a period of half-guessed-at bridge designs as the new Bessemer steels were used to replace the light wooden bridges for highways and railroads; and there were many bridge failures with heavy casualties. Railroad accidents were so common that a railroad magazine carried an editorial: "The Wreck of the Month."

head in a gunny sack in the coal of the tender to keep from smothering while passing through the tunnel. There is also the tip that a trackwalker's torch would flare away from the direction of an approaching train – a train invisible because of the smoke. An approaching train was even still invisible with the advent of an electric lighting system. One recalls the assurance of the Laurie and Latrobe reports that ventilation would not be a serious problem. We must remember that these men were thinking of locomotive engines that were small, with exhaust products of combustion trivial in amount to those of a modern steam locomotive. Improvements were made at the central shaft in 1877, with a thick masonry arch to intercept falling rocks, and with some attempt to promote better ventilation. Later incidents, although of less dramatic interest compared with the struggles of those who built the tunnel, reveal the progressive determination of the Boston and Maine Railroad to keep this valuable operating unit up to date. Of less tangible value is the legendary interest which the tunnel inspires among the employees of the railroad: from president to water boy, all are proud of their Hoosac Tunnel.

In the year 1899 powerful fans[12] were installed at the central shaft to alleviate the smoke problem. A decade later (1910–1911) the smoke really was conquered when the tunnel was electrified, the steam locomotive running "deadhead." The Diesel engine supplanted the electric in 1946. There were thus about 35 years of operation of each – the steam and the electric – and five years of the Diesel in the three-quarter century of tunnel service. But the increase in the size of locomotives made it an undersized tunnel: Therefore, a tough problem of construction during operation had to be undertaken in 1925. Miraculously, while trains still ran on approximate schedule, the rock floor of the tunnel was blasted out to allow the lowering of the track to give headroom for the largest modern cars or locomotives. Surely the men of the 1870's, looking on from their vantage point in the construction man's heaven, must have applauded this modern feat of construction.

Today, one quarter of a century later still, these old-timers, returning in spirit to their tunnel, would of course come by train, for they were railroad construction men. They would be confused by many new things – poignant examples of the tremendous increase in the power, weight, and speed of railroad equipment since their day. They would stare at the huge Diesels, drawing 100 freight cars or more; and they would, of course, examine the roadbed construction and note that the steel rails were at least twice as heavy as the iron rails of the 1870's. As smart Yankee mechanics, they would be intrigued with the intricate mechanisms of the all-electric centralized traffic control board, which governs the 14-mile-long section of railroad which embraces the tunnel. They would read

(*Concluded on page 168*)

[12] After an operation period of nearly half a century, these fans were replaced in 1945 by two modern fans, each having a capacity of 250,000 cubic feet a minute, and capable of giving two changes of the air in the tunnel per hour.

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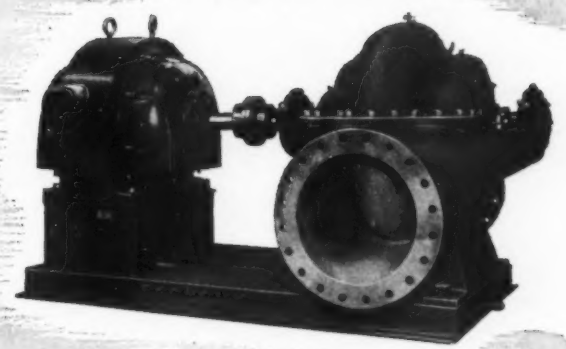

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DIEFENDORF GEARS

THE BLASTED BORE

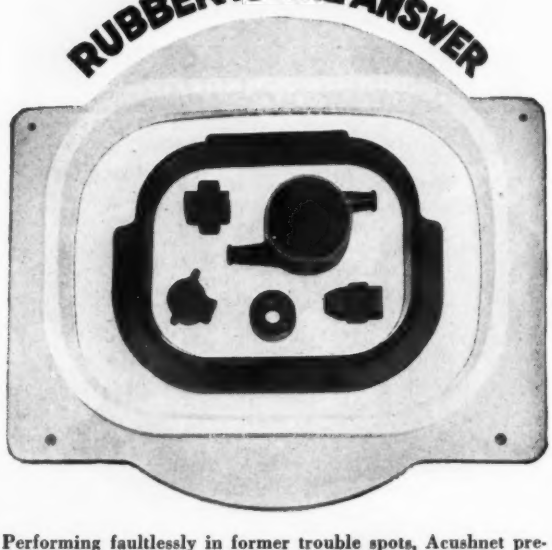
(*Concluded from page 167*)

the railroad posters that announce many vacation excursions. This last novelty, perhaps, would astonish an old-timer most; to learn that even working men of the mid-Twentieth Century must have their annual vacation from the arduous duties of modern life. In their day, vacations were for rich men who would go to Saratoga Springs or Bar Harbor. Locomotive engineers worked 70 hours a week in Massachusetts, at a maximum daily rate that had risen from $2.00 in 1851, to $3.45 in 1876, during the period of construction of the tunnel. Why should such highly paid men need a vacation?[13]

High above his tunnel, the returning old-timer would observe on the sharp Hairpin Bend of the vacationist's delight, the Mohawk Trail, not the elegant, six-horse coaches of his day, but smoothly swift lines of strange vehicles, which he would hear called automobiles. Via narrow and tortuous roads his guide would drive him down to the two portals of the Hoosac Tunnel. And the old-timer, no longer confused, would be content. It was his tunnel, looking exactly as he had left it. Barring an earthquake, it would remain undamaged for many centuries more, so well did he build, and so well had the railroad engineers who succeeded him repaired the normal ravages of time on his monument of pioneer tunnel construction.

[13] Today, it is not unusual for an engineer to receive $7,000 a year based on 20 nine-hour days a month.

RUBBER IS THE ANSWER



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A Report
TO M.I.T. MEN

In 1917 Walker Memorial Building was opened, a gift from Alumni for the welfare of M.I.T. students. In addition to including offices for student activities and serving as a student social center, this building houses the dining service.

In 1949–50 nearly one million meals were served to staff and students and 57 dances, receptions and balls were held in Morss Hall. Morss Hall seats approximately 500 people. Thus, each chair served 2,000 people per year or 5.5 persons per day. We thank the Alumni for making these services possible.

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TECHNOLOGICAL CHANGE AND SOCIAL POLICY

(*Continued from page 152*)

communication, power, metals, textiles, agricultural machinery, building – sociologist Bernhard J. Stern reported to the National Resources Committee the following finding: "From the results of this study it is apparent that the psychological factors of habit, fear, desire for personality equilibrium and status, and the tendency of groups to coerce their members to conformity, are latent predisposing factors toward resistance to change."[8]

In the next place, social policy must reckon with the need for maintaining free but well-financed programs of basic research (or so-called "pure science"). This is imperative since change, in a technological culture, is absolutely dependent on the free elaboration of scientific discovery and its subsequent linkage with technical application.

How important this problem is may be suggested by two illustrations. The first is the development of atomic energy research. With the Army and the Federal Bureau of Investigation in virtual, if not actual, control of atomic energy research, uninhibited research and communication on a national, as well as international basis, have been, except in a very limited way, throttled in recent years. Says Edward U. Condon of the National Bureau of Standards: "Prominent scientists are denied the privilege of traveling abroad. Physicists are not allowed to discuss certain areas of the science with each other, even as between individuals working on closely related phases of the same subject. They can only communicate through official channels, involving censorship of their communications by Army officers without knowledge and so without competence."[9]

This situation is usually defended in terms of security. But the motivations which lead to a dominated and fettered science involve far more than security risks. An instructive example is the story of German science during the days of the Nazi regime. As detailed by Samuel A. Goudsmit,[10] the Gestapo-ridden science of Hitlerite Germany fell prey to several easily imitated mistakes. These included: (1) complacency; (2) deterioration of interest in pure science; (3) regimentation in the administrative controls over research; (4) the hero worship of individual scientists; (5) the stifling secrecy of national security measures; (6) the failure to maintain open and widely used channels of communication among scientists themselves; (7) fanatical nationalism; and (8) doctrinaire dogmatism.

On the basis of a short article, "Physics in the USSR" appearing in *Physics Today*[11] which is attributed to Professor D. N. Nasledov, it is possible to elaborate on the effects of physics as practiced in Russia. Nasledov's article shows that Russian natural sciences, like the Hitlerite German science, also fall prey to many errors when the state attempts to dictate thinking, and especially when it attempts to mold science according to the brew of a cauldron of political dogma. To the eight points which have been outlined for Hitlerite

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TECHNOLOGICAL CHANGE AND SOCIAL POLICY

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German science, it is possible to add in the Russian case the additional errors of: (9) hero worship of the head of the state who, regardless of his own lack of qualifications in science, is regarded as a political lawgiver with whom all science must conform; (10) employing science primarily for militaristically aggressive purposes in furtherance of nationalistic political objectives; and (11) the casting of all thought into a mold guided by party lines where objectivity has no place.

Scientific research is a type of industrial work. To put the problem of free basic research in its simplest form, social policy must find and preserve ways of protecting the workmen, of providing them with tools, of securing the conditions of their work, and of encouraging organized attacks on meaningful problems.[12]

Again, social policy must reckon with the difficulty or impracticability of introducing for public use certain discoveries or improvements in our way of life. This has usually been referred to as the problem of "vested interests." Accusations have frequently been made by those who understand science and technology but imperfectly that desirable inventions and products have been intentionally withheld from public use, but such contentions have not been supported.

Another interesting case in point may be taken from the housing industry. Testifying before the Temporary National Economy Committee in July, 1939, when he was assistant attorney general, Thurman W. Arnold called attention to five types of building-trade restraints.[13] They consisted, he found, of price fixing by producers, restraints by distributors, restrictive practices by contractors and unions, as well as by legislative bodies. The consequences include inflexible prices, imperfect competition, inhibited productivity, thwarting of technological innovations and of experimentation in design, materials, and methods in such a way as to impede production.

Housing is merely one of a multitude of instances which show how advancements in the field of applied science, or technology, have been hamstrung by restrictive practices. It is indeed a familiar story in American history. There is very little comfort in the following testimony of the Inventors' Guild: "It is a well-known fact that modern trade combinations tend strongly toward constancy of processes and products, and by their nature are opposed to new processes and new products originated by independent inventors, and hence tend to restrain competition in the development and sale of patents and patent rights; and consequently tend to discourage independent inventive thought."[14]

Finally, it is wise to remember that social policy, with respect to proposed or anticipated innovations and their consequences, is necessarily an unfinished – even unfinishable – business. A culture which survives by ceaseless change can hardly find refuge in static formulas of control. Social policy in the field of technological change must, moreover, not only be dynamic but integral as well. This fact forms one of the

(Concluded on page 172)

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conclusions of a recent study of this problem sponsored by the Social Science Research Council. "The total examination of the field of technological change will require a team approach. Only by combining the work of economists, sociologists, psychologists, political scientists, and other specialists can the total cost and total effect of any given change be measured. . . . After the efforts of these specialists are combined, we will have the relevant data for the kinds of decisions that are attempted in modern social organizations."[15]

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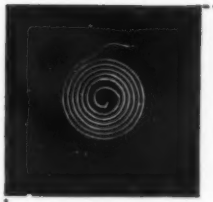

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THE UNCHANGEABLE SHIP

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broken by the construction of Gar Wood's *Venturi* which has received considerable publicity since 1949. The ship, 188 feet long with a total width of 40 feet, was built during World War II (under the designation TA-1) as a target ship simulating an aircraft carrier for bombing practice. But it was not used and was sold back to the inventor after the war.

Reduced to minimum wordage, Wood's claim is that the older catamarans failed for two reasons: the first and most obvious one is that they were underpowered; the second is that the shape of the twin hulls was wrong. The hulls of the older catamarans could have been used as single ships, except for the fact that their keels were off-center. Wood arrived at his new hull shape by taking a conventional ship, cutting it apart lengthwise, and placing the two halves some distance apart, but *transposed*, so that the two straight sides form the outside of the whole. Experimenting with models, Wood found, however, that the ship would travel on a straight course only if he did not round off the stern a little.

The *Venturi* has made trial runs off Miami in 1949, and attained 26 knots, virtually without rolling, even when a heavy sea was running. She is also reported to turn with a radius four times her own length. It is only natural that the inventor loves his invention and predicts a great future in which twin-hulled superliners for 4,000 passengers will attain an average speed of 36 knots. Well, it may be that the different hull shape actually makes all the difference. If so, it would be the first major change of the ship shape since its invention; a real change, not just an improvement. If this particular change wins out, it should be soon enough so that most of us will still be alive to see the day. In the meantime, it is useful to keep in mind how unchangeable the ship has proved to be in the past.

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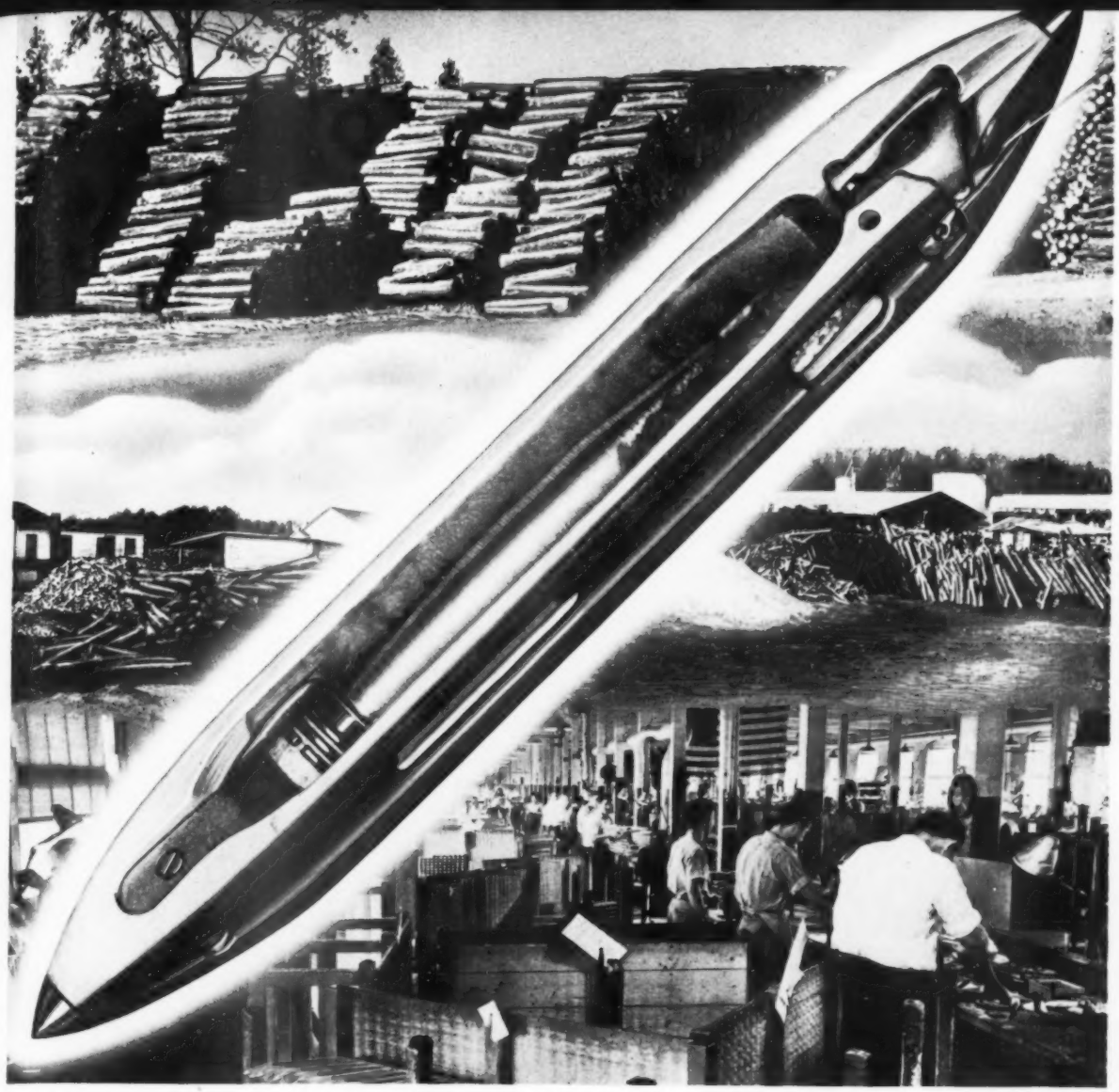

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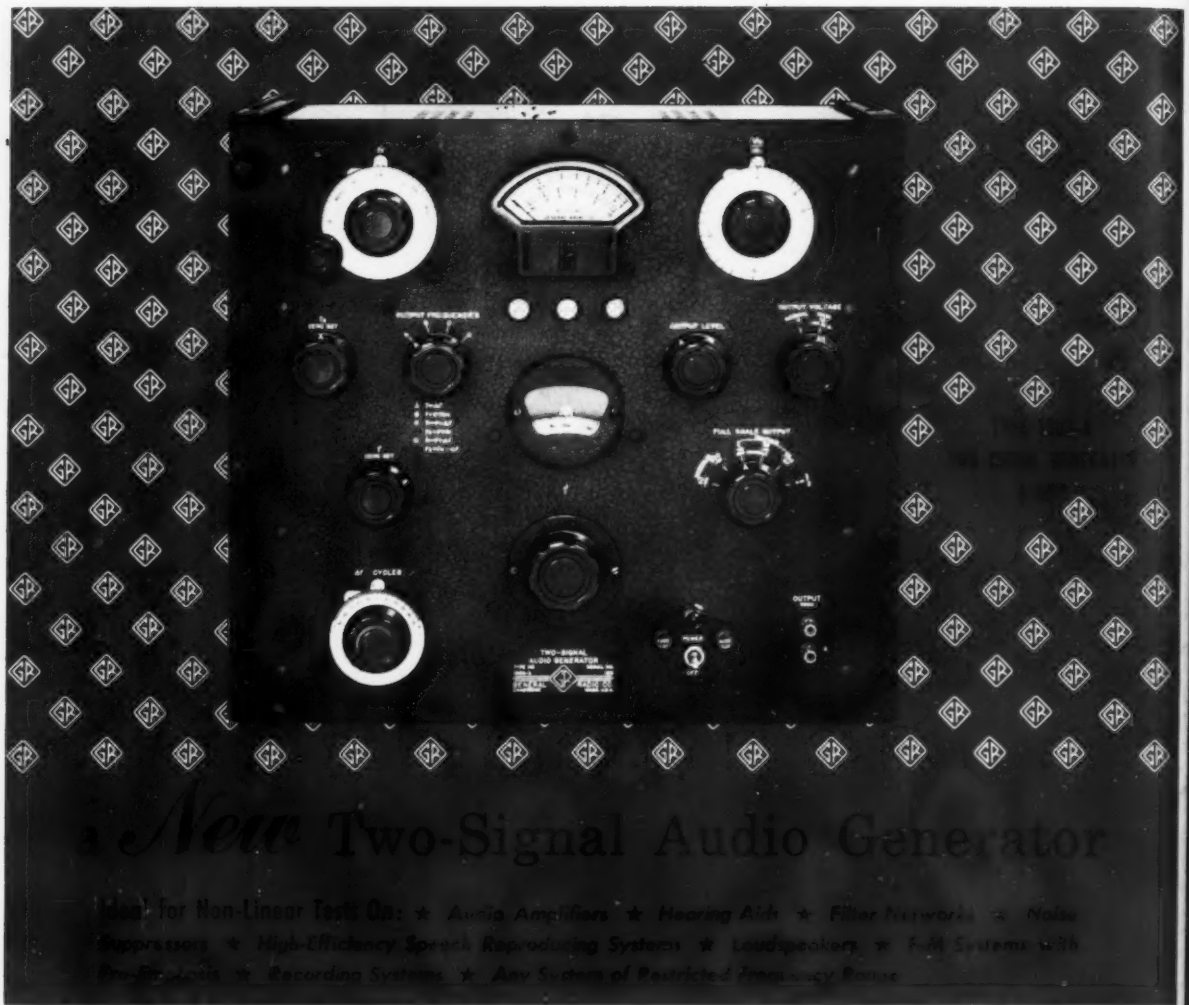

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